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AUTHOR	Madaus, George F.; And Others
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ABSTRACT

Bloom's taxonomy of the cognitive domain consists of six major levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. The purpose of this study is to construct a quantitative causal model for a set of tests designed to operationally define these six levels in order to further explore the validity of the cumulative hierarchical assumption of the taxonomy. (Author/AG)

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A CAUSAL MODEL ANALYSIS SUGGESTS MODIFICATION OF THE CUMULATIVE HIERARCHICAL STRUCTURE ASSUMED IN BLOOM'S TAXONOMY OF THE COGNITIVE DOMAIN

George F. Madaus Ronald L. Nuttall Elinor M. Woods

Boston College

INTRODUCTION

In the Taxonomy of Educational Objectives, Handbook I: Cognitive Domain, Bloom (1956) describes a "Taxonomy" consisting of six major levels. These levels were assumed to possess a cumulative hierarchical structure increasing in complexity from the simplest level, Knowledge, to Comprehension, to Application, to Analysis, to Synthesis, to the most complex level, Evaluation. The primary objective of the present study was to construct a quantitative causal model for Kropp and Stoker's (1966) set of tests designed to operationally define the six levels of the Taxonomy in order to explore further the validity of the cumulative hierarchical assumption of the Taxonomy. A secondary objective of the study was to determine the effect of introducing a g factor of general ability into the causal flow of the taxonomic structure.

The investigation of the validity of the cumulative hierarchical structure of the Taxonomy by Kropp and Stoker (1966) involved analysis of mean scores for taxonomic-type tests and the simplex structure of the matrix of intercorrelations. The simplex model attempts to find the best hierarchical order for the tests included in the correlation matrix so that each test is so ordered that its contents include everything in the preceding tests plus perhaps "something more" (Kaiser, 1967, p. 165). Thus, a simplex analysis of taxonomic-type tests should reveal the largest correlations occurring between adjacent levels, and the weakest correlations between the most simple and complex levels, of the assumed hierarchical order of the Taxonomy. In contrast to the simplex model, the causal model approach used in this study assists in identifying the "something more"--the indirect relationships. Although causality cannot be demonstrated from correlational data, the adequacy of any given causal model can be tested by the correlation coefficients which measure the amount of variation explained (Blalock, 1964). In other words, a simplex analysis reveals whether the over-all pattern of the intercorrelations for a set of taxonomic-type tests approximates the assumed order of complexity; that is, whether the direct relationship between adjacent levels is higher than between nonadjacent levels. However, it

does not analyze the indirect relationships within the pattern of intercorrelations. A causal model analysis reveals not only the proportion of variance in each level explained directly by the preceding adjacent level but also any proportion of variance explained indirectly by nonadjacent levels. Since the Taxonomy assumes a cumulative hierarchy, there should be no significant indirect relationships between nonadjacent levels. Thus, the causal model approach used in this study enables the validation of the adequacy of the model assumed by the structure of the Taxonomy by testing not only the consistencies revealed by the direct relationships but also any inconsistencies revealed by indirect relationships among the six major levels of the Taxonomy.

Kropp and Stoker's (1966) study is the most comprehensive study of the Taxonomy to date. Their study focused on three specific problems: (1) to test the hierarchical structure of the Taxonomy; (2) to determine whether the six major processes, aptitudes, or abilities which are described in the Taxonomy transcend subject-matter content; and (3) to determine the psychological structure of each of these major processes or abilities. On the basis of both mean performance and simplex analyses, the conclusion was drawn that the empirical data generally supported the imputed hierarchical structure of the Taxonomy. This conclusion was qualified by the finding of a systematic reversal of means on the Synthesis and Evaluation subtests for the science content taxonomy tests. The generality of process was not clearly supported; the data suggested that the specific test score being analyzed was determined by a highly complex interaction of content and process. In examining the psychological structure of each of the six major processesor abilities, Kropp and Stoker focused on determining whether each level of the Taxonomy can be defined by more elemental cognitive factors. They used factor scores from the Kit of Reference Tests (KIT) for Cognitive Factors to predict performance on subtests for each of the six major levels of the Taxonomy.

The question of whether more elemental cognitive factors can be defined for the six levels of the Taxonomy is highly relevant. Ebel (1966, 1969a and b) contends that mental ability rather than command of knowledge is measured by achievement tests constructed according to the Taxonomy. Ebel (1966) states that complex achievement taxonomy test items tend to "measure general ability more than specific knowledge." Kropp and Stoker (1966) cite a study by Thomas of the three lower levels of the Taxonomy. They report that the Thomas study and preliminary studies of their own suggest that "correlations between taxonomy-level scores and group intelligence scores decrease as the level increases and that correlations between taxonomy-level scores and reasoning ability scores increase as level increases (p. 39)." This would appear to support Ebel's hypothesis that taxonomic-type achievement tests may be measuring "_g_" rather than mastery of knowledge--at least for the Comprehension and Application levels of the Taxonomy. This assumes, of course, that Ebel's construct of "general mental ability" is equivalent to the more common construct of "_g_." Jensen (1969) describes Spearman as characterizing "_g_" as "'the ability to educe relations and correlates'--that is, to be able to see the general from the particular and the particular as an instance of the general (p. 9)." Interestingly this characterization of _g_ is highly similar to the description of the fourth level of complexity of the Taxonomy: "_Analysis_ emphasizes the breakdown of the materials into its constituent parts and detection of the

relationship of the parts and of the way they are organized (Bloom, 1956, p. 144)." Kropp and Stoker (1966) as noted above used separate factor scores obtained from a set of KIT subtests to predict performance for each of the six major levels of the Taxonomy but were unable to identify conclusively more elemental cognitive factors underlying each level of the Taxonomy. In contrast, this study extracted a $_g$ factor of general ability from Kropp and Stoker's data for the set of KIT subtests to determine its effect on the assumed causal flow of the taxonomic structure.

PROCEDURES

Sample

Four taxonomic-type tests were constructed and administered to grades 9-12 students in ten Florida schools from five county school systems by Kropp and Stoker (1966). Approximately 1,600 students at each of the four grade levels were administered the four taxonomic-type tests. Collectively the students represented a slightly above average group with respect to mental ability as determined by national norms. In addition, all the students in one of the schools were administered a set of the Kit of Reference Tests (KIT) for Cognitive Factors. The data for the subsample of grade 9-12 students (N=1,128) administered both the four taxonomic-type tests and the KIT tests were kindly made available by Stoker for the present study. It was necessary to remerge the taxonomy scores and the KIT scores of the Kropp and Stoker subsample for this study. The distributions by grade of the originally merged records reported by Kropp and Stoker and the remerged records used as the sample in this study are compared in Table 1. The remerging of the records for this study was done using four merge fields: student identification number, county code, school code and grade level. The original merging may not have included these particular four fields, and this may account for the addition of four students to the remerged data file constituting the sample used in this study.

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Insert Table 1 about here
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Taxonomy Tests

Each of the four taxonomic-type tests constructed by Kropp and Stoker consisted of six subtests corresponding to the major levels of the Taxonomy (Bloom, 1956). Kropp and Stoker (1966, p. 165) described the four tests as follows:

> The tests were of the reading comprehension type in that a reading passage which presented the relevant content appeared in each test booklet and the test items were based on the content of it. The reading passages were selected on the basis of their probable interest value, probable ease of comprehension, and their unfamiliarity to students. The latter two specifications are important because it is necessary that content mastery of students be relatively equal so that score variability will reflect differential mastery of the cognitive

processes. Of the four passages which were finally selected, two dealt with social science content, the Lisbon Earthquake and Stages of Economic Growth; and two dealt with science content, Atomic Structure and Glaciers.

Each test consisted of two parts. Part A included the Knowledge, Comprehension, Application, and Analysis items. Each of the subtests consisted of twenty four-choice items. Part B included the Synthesis and Evaluation items. There were five free-response Synthesis items and ten free-response Evaluation items. All subtests had a maximum possible score of twenty points.

The six subtests for each of the two science ("Atomic Structure" and "Glaciers") and the two social science ("Earthquake" and "Econ. Growth") tests were used as the taxonomy measures in this study.

General Data Analyses

The data processing and analyses were performed by an IBM 360/40 computer at the Boston College Computation Center, utilizing, for the most part, the Institute for Social Research Survey Analysis Software Package prepared by the University of Michigan (hereinafter referred to as OSIRIS). To arrive at a g factor of general ability, a principal components analysis was performed on the 63 KIT independent subtests administered to this sample. Separate principal component analyses (OSIRIS CORFAROT) were performed for each grade level and for the total sample (N=1,128). Coefficients of congruence (Harman, 1967, p. 270) were computed for the first unrotated principal component between each grade level and the total sample to determine the degree of factorial similarity. The four coefficients of congruence computed were all greater than .98; thus, the factor loadings for the first unrotated component for the total sample were used to compute the g-factor for all four grade levels. The g-factor score for each data case was obtained by weighting and summing the standard scores for the 18 KIT subtests[1] loading .50 or higher on the first component (OSIRIS ICON) and by adding a constant of 50.0 to the total weighted sum in order to avoid negative scores. Means, standard deviations and a correlation matrix for the scores on the six subtests of each of the four taxonomy tests and the g-factor were computed, excluding any missing observations (OSIRIS MDC), for each of the four grade levels separately. The correlation matrices were used as the bases for stepped forward and backward multiple regressions (OSIRIS ESSO) and partial correlations (OSIRIS PARCOR) computed in preliminary analyses prior to constructing and testing the causal model based on the cumulative hierarchical structure assumed by the Taxonomy.

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[1]Hidden Figures, Hidden Patterns 1 and 2, Copying Tests 1 and 2, Controlled Association, Association IV, Letter Sets, Division Tests 1 and 2, Symbol Production 1 and 2, Ship Destination, Necessary Arithmetic Operations, Logical Reasoning, Inference Test, Vocabulary, and Wide-Range Vocabulary.

Causal Model Analyses

The developers of the structure of the Taxonomy based their arrangement of cognitive behaviors from simple to complex "on the idea that a particular simple behavior may become integrated with other equally simple behaviors to form a more complex behavior (Bloom, 1956, p. 18)." Thus, Knowledge is made up of cognitive behaviors of Type A, Comprehension of Types A and B, Application of Types A, B and C, etc. Although they point out two alternative ways of viewing the more complex behaviors as either being completely analyzable into simpler components or as being more than the sum of the simpler behaviors, they state that either way "the simpler behaviors may be viewed as components of the more complex behaviors" (Bloom, 1956, p. 16).

The testing of the cumulative hierarchical structure of the taxonomic levels by the causal model approach involves measuring the strengths of the links between levels. The assumed hierarchy should have direct links between adjacent levels and should have no indirect links between nonadjacent levels. The magnitude of these direct and indirect links was measured by constructing a causal model using multiple regression procedures (OSIRIS ESSO). The Coefficient of Multiple Determination (R^2) can be interpreted as the proportion of variance of a dependent variable accounted for by independent variables. Since proportions of variance are additive, it is possible to subtract the amount of variance accounted for by a subset of independent variables from that accounted for by a larger set of independent variables. Any difference indicates the amount of unique variance accounted for by the additional variable(s).

The causal model method of analysis used in this study is outlined in Figure 1. Causal priority was assumed for the direct links between the adjacent

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Insert Figure 1 about here

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levels. Thus, for example, the strength of the assumed direct link between the adjacent levels of Knowledge (K) and Comprehension (C) is indicated by the size of $R^2_{C:K}$ (the dependent variable is the first subscript and the independent variable(s) are indicated by the subscript(s) after the colon). Similarly, the strength of the direct link between Comprehension and Application (AP) is indicated by the size of $R^2_{AP:C}$. The indirect link (i.e., the unique explained variance) between the nonadjacent levels of Knowledge and Application is indicated by the difference ($R^2_{AP:C,K} - R^2_{AP:C}$). If this difference is large, then Knowledge accounts for a unique part of the variance in Application after all the variance due to the direct link of Comprehension has been partialed out. Since the Type A behaviors of Knowledge are assumed by the taxonomic structure to be integrated with the Type B behaviors of Comprehension, the Types A and B behaviors of Application should be partialed out by the variance explained by Comprehension. There should be no relationship between the Type C behaviors accounting for the remaining variance of Application and the Type A behaviors accounting for the total variance of Knowledge. Moreover, if the behaviors for the lower levels are integrated with each additional level as the taxonomic

hierarchy assumes, the proportion of variance explained by the direct links between adjacent levels should increase steadily. To the extent that the direct links between adjacent levels do not increase steadily and any indirect links are substantial, the hierarchical nature of the taxonomic levels is brought into question.

Preliminary analyses prior to designing the causal model indicated a break in the assumed taxonomic hierarchy and suggested a Y-shaped structure. The stem of the Y consists of Knowledge to Comprehension to Application. Then one branch of the Y goes from Application to Analysis and the other branch from Application to Synthesis and Evaluation. This Y-shaped structure is discussed further in the results section. In designing the causal model to test the assumed hierarchical structure of the Taxonomy, the direct and indirect links not already implicitly included in the model which were required to test the suggested Y-shaped structure were added as an adjunct to the model. This involved adding three additional causal links to the model: a direct link from Application to Synthesis and indirect links from Knowledge and Comprehension. In addition, in order that the systematic reversal of means on the Synthesis and Evaluation subtests on the science content taxonomy tests found by Kropp and Stoker could not later be hypothesized to account for any consistent or inconsistent results obtained by the causal model analyses, the direct and indirect causal links outlined in Figures 1 and 2 were calculated for both the assumed hierarchical and the Y-shaped structures with Evaluation and Synthesis both in the reversed order as well as in the assumed hierarchical order.

Figure 2 outlines a parallel causal model method of analysis for determining the effect of introducing a g-factor of general ability into the causal flow of

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Insert Figure 2 about here

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the taxonomic structure. The g-factor was assumed to be causally prior to all the taxonomic levels. Its value is determined only by variables that are outside the causal system. It is what econometricians call an "exogenous" variable (Blalock, 1964, p. 54). If any indirect links between nonadjacent taxonomic levels are revealed by the analyses of the taxonomic structure outlined in Figure 1, these indirect links may be due to variance shared in common with a g-factor. By including a g factor explicitly in the causal model, any such common variance will be partialed out of the indirect links. The strength of the relationship of with any level (l) in the taxonomic hierarchy is indicated by $R^2_{l:G}$. Thus, the influence of g on Knowledge is $R^2_{K:G}$. To measure the direct link between adjacent levels of the hierarchy, the influence due to g must be removed since that influence has been assumed to be causally prior. This is measured by subtraction of $R^2_{l:G}$ from the R^2 due to <u>both</u> g and the adjacent lower level. The strength of the direct link, for example, between Synthesis (S) and Evaluation (E) is indicated by the difference $(R^2_{E:G,S} - R^2_{E:G})$.

Since there were four taxonomy tests and four grade levels, for purposes of this study each was considered to be a replication. Consequently, 16

replications of each of the causal model analyses outlined in Figures 1 and 2 were obtained. Since the analyses utilized proportions of variance which are additive, it was possible to summarize the findings for the 16 replications by computing means and sample standard deviations for the variances for each of the direct and indirect links shown in these figures in three ways: (1) by content across the four grades, (2) by grade across the four contents, and (3) across contents and grades for all 16 replications.

RESULTS AND DISCUSSION

Preliminary Analyses

Prior to constructing and testing the causal models outlined in Figures 1 and 2, stepped forward and backward multiple regressions were performed. The stepped forward regressions started with the g-factor of general ability and cumulatively predicted each taxonomic level from Knowledge to Evaluation. The results indicated a break in the assumed taxonomic hierarchy and suggested a Y-shaped structure. A description of the Y-shaped structure suggested was given in the causal model analyses subsection above. The essential nature of this Y-shaped structure is that there is no relationship between Analysis and Synthesis; instead, Synthesis is directly linked to Application. Figure 3 illustrates the Y-shaped structure and compares it with the cumulative hierarchical structure. The numbers in each circle indicate the proportion of variance (R^2) in that level as determined by the previous level(s) and the g-factor. The data underlying this figure are presented in Tables 2, 3 and 4. These tables indicate the proportion of variance accounted for by multiple regressions following the cumulative hierarchical and the Y-shaped structures. These results are summarized by grade across contents in Table 2 and by content across grades in Table 3. Table 4 reports the means (which form the basis for Figure 3) and sample standard deviations for the total 16 replications. In Figure 3 the crucial comparison across the 16 replications is between the $R^2_{S:G,K,C,AP,AN}$ of the cumulative hierarchical structure and the $R^2_{S:G,K,C,AP}$ of the Y-shaped structure. The average variance of .234 of the former in comparison to the average variance of .220 of the latter across the 16 replications indicates that the inclusion of Analysis in the predictors of Synthesis explains only an additional .014 of the variance. Moreover, no difference between the standard deviations for these two averages is revealed in Table 4. The curvilinear pattern of the proportions of variance explained over the six taxonomic levels should be noted. The proportions of variance increase steadily at the lower levels from Knowledge to Application and then decrease at the higher levels from Analysis to Evaluation. This pattern will be discussed later at greater length.

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Insert Tables 2-4 and Figure 3 about here

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As a further check of the assumed hierarchy, partial correlations between nonadjacent levels were computed. For example, the correlation between Knowledge and Application with Comprehension partialed out was computed. In order for the

assumed taxonomic hierarchy to hold, the partial correlations between nonadjacent levels should be zero. However, in general, the partial correlations were strong indicating indirect influences between nonadjacent levels. The partial correlations support the Y-shaped structure suggested by the regression analyses. When the g-factor and Knowledge to Application levels composing the stem of the Y are partialed out, there is a near vanishing of the relationship between Analysis and Synthesis for eleven of the sixteen replications.

Causal Model Analyses

Tables 5 and 6 report the means and sample standard deviations for the total 16 replications for each of the direct and indirect causal links outlined in Figures 1 and 2, respectively. The proportions of variance accounted for by each of the direct and indirect causal links outlined in Figure 1, together with means and sample standard deviations, are summarized by grade across contents and by content across grades in Tables 7-14. Parallel data for the direct and indirect causal links with the removal of the g-factor outlined in Figure 2 are summarized in Tables 15-22. The direct and indirect causal link averages ($R^2 \geq .04$) of the causal model analyses outlined in Figures 1 and 2 are summarized for the total 16 replications, by grade across the four contents and by content across the four grades in Figures 4-22. These figures are arranged in pairs by the alternate designs to compare more easily the effect of including the G-factor in the analysis of the model outlined in Figure 2 on the direct and indirect causal links analyzed by the model outlined in Figure 1.

Insert Tables 5-22 and Figures 4-22 about here

In order to determine whether the systematic reversal of means on the Synthesis and Evaluation subtests on the science content taxonomy tests found by Kropp and Stoker were reflected in the causal model analyses, proportions of variance for the direct and indirect causal links outlined in Figures 1 and 2 were calculated for both the hierarchical and Y-shaped structures with Synthesis and Evaluation in both the assumed hierarchical order as well as in the reversed order. These calculations are reported in Table 23, and a comparison of the results indicates that 25 of the 28 average variances between Application or Analysis with Synthesis are larger than Application or Analysis with Evaluation. The indirect link between Knowledge to Evaluation is slightly higher than between Knowledge to Synthesis in three cases. These results thus reveal a consistently stronger relationship between Application or Analysis with Synthesis than with Evaluation and support the retention of Synthesis and Evaluation in their assumed hierarchical order in the causal models tested in this study.

Insert Table 23 about here

Analyses for Total 16 Replications

The discussion of the causal model results will focus primarily on an examination and comparison of Figures 4 and 5. The summary of the direct and indirect causal link averages for the total 16 replications is presented in Figure 4 for the model not including the g factor of general ability. Figure 5 summarizes the results when the g factor is explicitly included in the model. Figure 6 is a redrawing of Figure 5 to depict more clearly its structure. The authors feel that Figure 6 is the best representation of the structure underlying the Taxonomy as operationally defined by the Kropp and Stoker set of tests.

The summary of the direct and indirect causal link averages for the total 16 replications presented in Figure 4 indicates that out of the ten indirect links which are possible between nonadjacent levels in the assumed hierarchical structure, eight strong indirect links ($R^2 \geq .04$) exist. However, Figure 5 shows that when the influence of the g-factor of general ability is removed from the indirect links, only one indirect link remains for the total 16 replications--Comprehension to Analysis. Comprehension appears to account for a unique amount of variance in Analysis, even after controlling for both the g-factor and Application. An examination of Figures 7-22 indicates that this indirect link between Comprehension and Analysis is the most consistent indirect link between nonadjacent levels both with and without the g-factor included in the model.

A comparison of Figures 4 and 5 reveals not only that the indirect links between nonadjacent levels are reduced by inclusion of the g-factor but also that the direct links between adjacent levels are extremely dependent on the g-factor. The direct links between the adjacent levels at the lower end of the assumed hierarchy show a considerable reduction, and the direct links between Analysis to Synthesis and Synthesis to Evaluation become too weak to be retained in the model. Substantially all of the observed direct relationships between Analysis to Evaluation indicated in Figure 4 are due to common variance with the g-factor.

In contrast to the loss of the direct link between Analysis and Synthesis indicated in Figure 5, it should be noted that the direct link between Application and Synthesis included as an adjunct for testing the Y-shaped structure suggested by the preliminary analyses, although affected by the removal of the g-factor, remains sufficiently strong to be retained in the model. In addition, the direct link of .154 between Application and Synthesis in comparison to the direct link of .108 between Analysis and Synthesis indicated in Figure 4 further lends support to the Y-shaped structure in contrast to the assumed hierarchical structure for the Taxonomy. Moreover, in all the causal model results reported in Figures 7-22 by grade across contents and by content across grades for the cumulative hierarchical and the Y-structure models with and without the g-factor, the direct link between Application and Synthesis is consistently stronger than the direct link between Analysis and Synthesis.

The pattern of the direct relationship between the g-factor and the three lower levels in Figure 5 confirms the pattern of an increasing relationship between the three lower levels and a general reasoning ability as found in the Thomas study and preliminary investigations of Kropp and Stoker discussed in the introduction. However, the pattern is reversed for the three higher levels. The relationship of the g-factor decreases as the levels become more complex. This pattern is not only reflected in the relationship between the upper levels and the g-factor but in the decline in the direct relationship between the adjacent levels from Analysis to Evaluation. Figure 3 also indicated that the pattern of the total proportion of variance predicted was curvilinear with the Synthesis and Evaluation levels being less predictable than levels lower in the hierarchy. If the behaviors for the lower levels were integrated with each additional level as the taxonomic hierarchy assumes, the proportion of variance explained should increase steadily.

In the construction of these taxonomy tests, the four lower levels consisted of multiple-choice items and the two highest levels of free-response items. The difference in method of measurement could reasonably be hypothesized to explain the decline in the pattern found between Analysis and Synthesis since the form of measurement has changed. However, this "method of measurement" explanation cannot explain the further decline in the pattern from Synthesis to Evaluation. Since both these tests were free-choice format, the relationship should logically increase somewhat if the tests share a larger amount of "method" variance.

Cox and Unks (1967) report an unpublished doctoral dissertation study by Schmadel regarding the relationship of creative thinking abilities to achievement. Tests of evaluation and synthesis were constructed in the study and correlated very low with other achievement measures. Similarly the relationships between measures of divergent thinking and intelligence have generally been quite low (Madaus, 1967). Yet if the Evaluation and Synthesis subtests in this study show a low relationship to the lower levels of the Taxonomy and the g-factor because they are measures of divergent thinking, this still leaves unexplained the direct relationship between these two levels being lower than the direct relationship between Analysis and Synthesis or Application and Synthesis. Since verbal subtests of divergent thinking generally have very high intercorrelations, the correlation between Evaluation and Synthesis could be expected to be higher than observed if they are tapping the trait of divergent thinking.

Further, the inter-judge reliabilities reported for the Synthesis and Evaluation subtests by Kropp and Stoker (1966, p. 71) for the total sample ranged from .71 to .89. Thus, an hypothesis of a lower bound being set on the relationship between these two levels because of <u>scorer</u> unreliability cannot be supported.

Analyses by Grade across Contents

Another hypothesis for the decline in the relationship of the higher levels with the g-factor is suggested by an examination of Figures 7-14. These figures summarize the analyses for the four groupings by grade across contents

for the cumulative hierarchical and the Y-structure models with and without the g-factor. When the analyses are compared by grade, a grade trend emerges. For grades 9 and 10, when the g factor is not included, there are many indirect linkages which all (with the exception of the Comprehension to Analysis link discussed previously) disappear when the g-factor is included in the model. Similarly for these grades, the direct links between Analysis to Synthesis and Synthesis to Evaluation also disappear when the g-factor is included. However, this pattern changes in the 11th grade. The direct links between Analysis to Synthesis and from Synthesis to Evaluation, as well as several indirect links from the lower levels, remain sufficiently strong after the inclusion of the g-factor to be retained in the model for grades 11 and 12. In addition, the direct relationship of the g-factor to both Synthesis and Evaluation shows a grade trend reflecting a decline in the variance explained. The relationship of the g factor to Evaluation declines from a high of .166 in grade 9 to a low of .040 in grade 12.

Although Kropp and Stoker (1966) report multiple difficulties encountered with the Synthesis and Evaluation subtests, because of the similarity in the measurement problems, most of them should still have produced higher intercorrelations between these two subtests than between either of these levels with a lower level. However, in discussing the reversal of the Synthesis and Evaluation means on the science content tests which their analyses revealed, Kropp and Stoker (1966) remark that the effect of the difficulties encountered with grasping the principles, concepts and generalizations in the science tests "was somewhat cushioned on the Evaluation items because at least half of them required students to use external criteria in reaching an item response (p. 89)." They concluded that the "external criteria" were largely "'common sense,' an attribute in which the students appear not to be lacking (p. 89)." The foregoing remarks by Kropp and Stoker and the grade trends found in Figures 7-14 of a decrease in the g-factor relationships and an increase in the indirect relationships with the lower taxonomic levels as the grade level increases seem to support the hypothesis that the lower grade levels were more dependent on the g-factor in answering the subtests, especially the Synthesis and Evaluation subtests, while the higher grade levels were more dependent on the material presented for them to learn. The 9th and 10th graders appear to not yet have the <u>cultivated</u> "common sense" of the 11th and 12th graders and were thus more dependent on g in their performance, particularly on the Synthesis subtests.

Analyses by Content across Grades

Figures 15-22 summarize the analyses for the four groupings by content across grades for the cumulative hierarchical and the Y-structure models with and without the g-factor. Kropp and Stoker (1966, p. 89) found that the science content taxonomy subtests collectively were more difficult than the social science taxonomy subtests. This finding is supported by Figures 15-22. The direct causal links between the higher levels and the indirect causal links between the lower levels with the higher levels in the model without the g-factor for the science contents of Atomic Structure and Glaciers in Figures 16 and 18 reflect a strong dependence on the g factor. In contrast, the direct links between the higher levels are sufficiently strong in Figures 20 and 22 even

after the removal of the influence of the g-factor to be retained in the model for the social science contents of Earthquake and Econ. Growth. The model for Econ. Growth in Figure 22 shows strong indirect contributions of the three lower levels to the higher levels. Knowledge makes not only a strong indirect contribution to the variance of Synthesis but also a unique contribution indirectly to the variance of Evaluation. These results seem also to support the foregoing hypothesis indicated by the grade trend. When the content of the taxonomy tests consists of sufficiently unfamiliar or difficult material and behaviors at the lower level have not been learned, developed or integrated to make strong direct or indirect contributions to the higher levels, performance on the Synthesis and Evaluation subtests becomes highly dependent on g. The Synthesis and Evaluation subtests become more a measure of general mental ability rather than of knowledge or specific abilities.

SUMMARY AND CONCLUSIONS

The first objective of the study was to construct a quantitative causal model for Kropp and Stoker's set of four taxonomy tests designed to operationally define the six levels of the Taxonomy in order to explore further the validity of the cumulative hierarchical assumption of the Taxonomy. The testing of the cumulative hierarchical taxonomic structure by the causal model design postulated in Figure 1 indicated a decline in the magnitude of the direct links between adjacent levels as the levels become extremely complex and numerous indirect links between nonadjacent levels. Since the taxonomic hierarchy assumes that the behaviors of the lower levels are integrated cumulatively with each additional level, the magnitude of the direct links should increase between adjacent levels as the levels become more complex and there should be no indirect links between nonadjacent levels. The tests of the model described in Figure 1 call into question the validity of the assumed hierarchical structure of the Taxonomy and/or the construct validity of the Kropp and Stoker tests.

The secondary objective of the study was to determine the effect of introducing a g-factor of general ability into the causal flow of the taxonomic structure. The g-factor was assumed to be causally prior to all the taxonomic levels. The testing of the effect of the g-factor on the cumulative hierarchical taxonomic structure by the causal model postulated in Figure 2 showed that the direct links between the adjacent lower levels from Knowledge to Analysis decrease considerably in magnitude and between the adjacent higher levels from Analysis to Evaluation in general become too weak to be retained in the model. In addition, the indirect causal links decrease considerably in magnitude and number. Thus, these tests revealed that the direct and indirect causal links of the cumulative hierarchical taxonomic structure were extremely dependent on the g-factor. However, this general conclusion was qualified by the interaction of a grade and content trend. As the grade level increases and the content of the taxonomy test consists of more familiar material, the direct links between the adjacent higher levels from Analysis to Evaluation and of the indirect links between the three lower levels and the higher levels become sufficiently stronger

in magnitude to be retained in the model. In the lower grades (i.e., grades 9 and 10) or when the content of the taxonomy test is sufficiently unfamiliar, the Synthesis and Evaluation subtests are highly dependent on g and appear to be measuring general mental ability rather than knowledge or specific abilities. When the g-factor is introduced, the assumed hierarchy of the Taxonomy holds only for the direct links between the three lower levels for the total 16 replications.

Stepped regressions and partial correlations computed indicated a break in the assumed taxonomic hierarchy and suggested a Y-shaped structure. The stem of the Y consisted of Knowledge to Comprehension to Application. Then one branch of the Y went from Application to Analysis and the other branch from Application to Synthesis and Evaluation. The causal model designs outlined in Figures 1 and 2 for testing the cumulative hierarchical taxonomic structure included as an adjunct the direct and indirect links not already implicitly contained in the model which were required to test the Y-shaped structure suggested by the stepped regression and partial correlation analyses. In the causal model analysis for the total 16 replications in which the effect of the g-factor was removed, in contrast to the loss of the direct link between Analysis and Synthesis, the direct link between Application and Synthesis remained suffiently strong to be retained in the model. Moreover, in all eighteen causal model analyses, the direct link between Application and Synthesis was consistently stronger in magnitude than the direct link between Analysis and Synthesis. The causal model analyses thus lend support to the Y-shaped taxonomic structure.

These findings strongly indicate that all the simpler behaviors of the lower levels do not cumulatively become components of the more complex levels as assumed by the Taxonomy. Knowledge has been described in the Taxonomy as a construct consisting of Type A behaviors. These Type A behaviors are described as being integrated with Type B behaviors to become the more complex construct Comprehension. The results of this study suggest that the Type A behaviors of Knowledge could be viewed as a vector consisting of n-unique elements, that is:

$$A = \left[a_1, a_2, a_3, \ldots, a_n\right]$$

It could be hypothesized that Comprehension integrates the elements a_1 and a_2 with its vector B behaviors. However, Application consists of not only elements a_1 and $a2$ but a_3 as well. Thus Knowledge is able to explain a unique portion of Application not explained by Comprehension. Rather than the total vector A which we call Knowledge being integrated completely into Comprehension, instead a subset of specific elements of vector A is integrated into each of the more complex levels. This vector hypothesis may explain why Comprehension consistently accounted for a unique amount of variance in Analysis in the causal model analyses, with or without the inclusion of the g-factor.

This vector hypothesis also suggests an explanation for the decline in the contributions of the four lower levels to Synthesis and Evaluation. The findings indicate that performance on Synthesis and Evaluation in grades 9 and 10 is

highly determined by the g-factor and in grades 11 and 12 by direct and indirect contributions from the lower levels. However, a greatly reduced portion of the variance in these two levels is explained in comparison to the variance explained for each of the four lower levels. Not only are the two higher levels measuring behaviors in general which are not elements of the four lower levels but they are also measuring behaviors which are more unique than common to each other. Additional vectors consisting of behavioral elements other than those included in the four lower levels appear to be required to increase the portion of variance explained in either Synthesis or Evaluation. Whether these vectors would consist of elements of divergent thinking or a more abstract "g" (such as measured by the Raven's Progressive Matrices) remains to be answered.

Assuming that Ebel's construct of "general mental ability" is equivalent to "g," the results of this study generally support the conclusion of Ebel (1966) that complex achievement taxonomy test items tend to "measure general ability more than specific knowledge." Ebel (1969a and b) proposes two levels of learning: acquisition of knowledge and mastery of knowledge. The theory of a two-level structure of learning is also suggested by Cattell and Jensen. Jensen (1969, p. 13) describes Cattell as distinguishing between two aspects of intelligence: fluid and crystallized intelligence. Crystallized intelligence is defined as a precipitate out of experience, consisting of acquired and developed intellectual skills. Fluid intelligence, in contrast, is defined as the capacity for new conceptual learning and problem solving, relatively independent of education and experience. Jensen (1969, p. 110) hypothesizes two distinct basic processes underlying intelligence: associative learning and conceptual and abstract problem solving learning.

It would seem that Cattell's and Jensen's second levels should be unrelated to Ebel's second level--mastery of knowledge. Based on the Y-shaped structure suggested by the findings of this study, it is tentatively suggested that Ebel's two levels of achievement and Cattell's crystallized level of intelligence could be measured by the Y stem from Knowledge to Comprehension to Application to the Y branch of Analysis. However, in order for these four levels of the Taxonomy to measure "achievement" behaviors, Ebel (1969a and b) would point out that the educational objectives formulated must be stated in terms of achieved knowledge or specific ability rather than in terms of desired behavior and general abilities. The measurement of achievement dependent on learning and experience would end with the Analysis level. Cattell's fluid level and Jensen's conceptual level of intelligence might be highly related to the Y branch of Synthesis to Evaluation which showed a high dependence on g and slight dependence on previous learning for the lower grade levels.

The developers of the Taxonomy viewed that the levels of behavior measured thereby could be built up from the simple to the complex by the educational process (Bloom, 1956, p. 16). Since the Taxonomy consists of achievement behaviors, the results of this study suggest that Synthesis and Evaluation may not be highly dependent on the objectives of classroom instruction per se. It

should be emphasized that the problem of validating the Taxonomy also involves the construct validity of the measures used. Thus the question of the interaction between achievement and "*g*" at the upper levels of the Taxonomy raised by this study deserves further investigation. Given the widespread use of the Taxonomy in formulating classroom objectives in a multitude of curricula areas, for various types of students at differing levels of education, further investigation of the Taxonomy's assumptions would not be without considerable practical value. The developers of the Taxonomy themselves did not regard it as completed or perfected and anticipated revising the Handbook for the Taxonomy as experience dictated the need for modification (Bloom, 1956, p. 24).

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TABLE 1

Distribution by Grade of Originally Merged Records of Kropp and Stoker Subsample and Remerged Records Used as the Sample in This Study

	Subsample Reported in Kropp and Stoker	Sample Used in This Study
Grade 9	300	303
Grade 10	275	276
Grade 11	282	282
Grade 12	267	267
Total	1,124	1,128

Table 2

Summary of Proportions of Variance by Grade Across Contents
Grade 9 (N=303)

Proportion of Variance	Atomic Struc.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2K:G	.233	.262	.197	.254	.236	.025
R^2C:G,K	.214	.261	.412	.321	.302	.074
R^2AP:G,K,C	.316	.349	.450	.504	.405	.076
R^2AN:G,K,C,AP	.316	.417	.402	.383	.379	.039
R^2S:G,K,C,AP,AN	.106	.081	.375	.265	.207	.120
R^2E:G,K,C,AP,AN,S	.189	.245	.238	.288	.240	.035
Y Branch:						
R^2S:G,K,C,AP	.104	.081	.360	.264	.202	.115
R^2E:G,K,C,AP,S	.187	.243	.236	.283	.237	.034

Grade 10 (N=276)

Proportion of Variance	Atomic Struc.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2K:G	.331	.298	.248	.204	.270	.048
R^2C:G,K	.294	.350	.473	.364	.370	.065
R^2AP:G,K,C	.429	.519	.510	.537	.499	.041
R^2AN:G,K,C,AP	.310	.364	.434	.382	.372	.044
R^2S:G,K,C,AP,AN	.209	.161	.373	.235	.244	.079
R^2E:G,K,C,AP,AN,S	.288	.282	.203	.288	.265	.036
Y Branch:						
R^2S:G,K,C,AP	.182	.162	.372	.235	.238	.082
R^2E:G,K,C,AP,S	.275	.280	.203	.282	.260	.033

Grade 11 (N=282)

Proportion of Variance	Atomic Struc.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2K:G	.180	.196	.195	.129	.175	.027
R^2C:G,K	.267	.428	.352	.397	.361	.061
R^2AP:G,K,C	.540	.495	.536	.562	.533	.024
R^2AN:G,K,C,AP	.495	.346	.495	.386	.430	.066
R^2S:G,K,C,AP,AN	.151	.250	.366	.310	.269	.080
R^2E:G,K,C,AP,AN,S	.167	.217	.124	.249	.189	.048
Y Branch:						
R^2S:G,K,C,AP	.148	.145	.359	.308	.240	.095
R^2E:G,K,C,AP,S	.167	.215	.123	.249	.188	.048

Table 2 - Continued

Grade 12 (N=267)

Proportion of Variance	Atom Struc.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2K:G	.092	.163	.247	.046	.137	.076
R^2C:G,K	.215	.270	.276	.257	.254	.024
R^2AP:G,K,C	.424	.423	.503	.516	.466	.043
R^2AN:G,K,C,AP	.317	.295	.452	.437	.375	.070
R^2S:G,K,C,AP,AN	.206	.160	.258	.234	.214	.036
R^2E"G,K,C,AP,AN,S	.139	.127	.131	.165	.140	.015
Y Branch:						
R^2S:G,K,C,AP	.193	.152	.228	.225	.199	.031
R^2E:G,K,C,AP,S	.137	.102	.108	.163	.127	.024

TABLE 3

Summary of Proportions of Variance by Content Across Grades

Atomic Structure

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
$R^2K{:}G$	.233	.331	.180	.092	.209	.087
$R^2C{:}G,K$	.214	.294	.267	.215	.247	.034
$R^2AP{:}G,K,C$	.316	.429	.540	.424	.427	.079
$R^2AN{:}G,K,C,AP$	.316	.310	.495	.317	.359	.078
$R^2S{:}G,K,C,AP,AN$	.106	.209	.151	.206	.168	.043
$R^2E{:}G,K,C,AP,AN,S$	.189	.288	.167	.139	.196	.056
Y Branch:						
$R^2S{:}G,K,C,AP$	.104	.182	.148	.193	.157	.035
$R^2E{:}G,K,C,AP,S$	.187	.275	.167	.137	.191	.051

Glaciers

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N-267)	Mean	Sample Stan. Dev.
$R^2K{:}G$	.262	.298	.196	.163	.230	.053
$R^2C{:}G,K$	.261	.350	.428	.270	.327	.068
$R^2AP{:}G,K,C$	.349	.519	.495	.423	.446	.066
$R^2AN{:}G,K,C,AP$	.417	.364	.346	.295	.355	.044
$R^2S{:}G,K,C,AP,AN$	.081	.161	.250	.160	.163	.060
$R^2E{:}G,K,C,AP,AN,S$	.245	.282	.217	.127	.218	.057
Y Branch:						
$R^2S{:}G,K,C,AP$	.081	.162	.145	.152	.135	.032
$R^2E{:}G,K,C,AP,S$	.243	.280	.215	.102	.210	.066

Earthquake

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
$R^2K{:}G$	.197	.248	.195	.247	.222	.026
$R^2C{:}G,K$	.412	.473	.352	.276	.378	.073
$R^2AP{:}G,K,C$	.450	.510	.536	.503	.500	.031
$R^2AN{:}G,K,C,AP$	.402	.434	.495	.452	.446	.034
$R^2S{:}G,K,C,AP,AN$	.375	.373	.366	.258	.343	.049
$R^2E{:}G,K,C,AP,AN,S$	.238	.203	.124	.131	.174	.048
Y Branch:						
$R\ S{:}G,K,C,AP$	.360	.372	.359	.228	.330	.059
$R\ E{:}G,K,C,AP,S$	.236	.203	.123	.108	.167	.054

Table 3 - Continued

Econ. Growth

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
$R^2K:G$	.254	.204	.129	.046	.158	.079
$R^2C:G,K$	.321	.364	.397	.257	.335	.052
$R^2AP:G,K,C$	.504	.537	.562	.516	.530	.022
$R^2AN:G,K,C,AP$	.383	.382	.386	.437	.397	.023
$R^2S:G,K,C,AP,AN$	.265	.235	.310	.234	.261	.031
$R^2E:G,K,C,AP,AN,S$	.288	.288	.249	.165	.247	.050
Y Branch:						
$R^2S:G,K,C,AP$	.264	.235	.308	.225	.258	.032
$R^2E:G,K,C,AP,S$						

TABLE 4

Summary of Proportions of Variance for Total 16 Replications

Proportion of Variance	Mean	Sample Stan. Dev.
$R^2K:G$	.205	.071
$R^2C:G,K$	.322	.075
$R^2AP:G,K,C$	.476	.069
$R^2AN:G,K,C,AP$	.389	.061
$R^2S:G,K,C,AP,AN$	.234	.088
$R^2E:G,K,C,AP,AN,S$	.209	.060
Y Branch:		
$R^2S:G,K,C,AP$	.220	.089
$R^2E:G,K,C,AP,S$	.203	.062

Table 5

Means and Sample Standard Deviations for Proportions of Variance for Direct and Indirect Links for Figure 4: Total 16 Replications

Proportion of Variance	Mean	Sample Standard Deviation
$R^2 C:K$	.213	.073
$R^2 AP:C$	.396	.077
$R^2 AN:AP$	.307	.080
$R^2 S:AP$	.153	.073
$R^2 S:AN$	.108	.061
$R^2 E:S$	.085	.039
$R^2 AP:C,K$	.439	.069
$R^2 AN:AP,C$	.372	.064
$R^2 S:AP,C$	.184	.082
$R^2 S:AN,AP$	.169	.079
$R^2 E:S,AN$	.121	.041
$R^2 AN:AP,K$	.316	.080
$R^2 S:AN,C$	.168	.079
$R^2 E:S,AP$	.143	.047
$R^2 S:AP,K$	.187	.078
$R^2 S:AN,K$	.169	.074
$R^2 E:S,C$	.140	.052
$R^2 E:S,K$	.146	.043
$R^2 AP:C,K - R^2 AP:C$	.043	.020
$R^2 AN:AP,C - R^2 AN:AP$	.065	.030
$R^2 S:AN,AP - R^2 S:AN$	.061	.036
$R^2 E:S,AN - R^2 E:S$	.036	.026
$R^2 AN:AP,K - R^2 AN:AP$	.009	.012
$R^2 S:AP,C - R^2 S:AP$	.030	.020
$R^2 S:AN,C - R^2 S:AN$	.060	.038
$R^2 E:S,AP - R^2 E:S$	.058	.040
$R^2 E:S,C - R^2 E:S$	.055	.045
$R^2 S:AP,K - R^2 S:AP$	.034	.022
$R^2 S:AN,K - R^2 S:AN$	.061	.030
$R^2 E:S,K - R^2 E:S$	.060	.048

Table 6

Means and Sample Standard Deviations for Proportions of Variance for Direct and Indirect Links with G-Factor for Figure 5: Total 16 Replications

Proportion of Variance	Mean	Sample Standard Deviation
$R^2K:G$	.205	.071
$R^2C:G$	.249	.057
$R^2AP:G$	.283	.072
$R^2AN:G$	.178	.048
$R^2S:G$	.134	.068
$R^2E:G$	.118	.064
$R^2C:G,K$	.322	.075
$R^2AP:G,C,$	.453	.070
$R^2AN:G,AP$	.335	.077
$R^2S:G,AP$	.194	.080
$R^2S:G,AN$	.174	.077
$R^2E:G,S$	.156	.052
$R^2AP:G,C,K$	.476	.069
$R^2AN:G,AP,C$	.384	.063
$R^2S:G,AP,C$	.211	.085
$R^2S:G,AN,AP$	.206	.083
$R^2E:G,S,AN$	.169	.055
$R^2AN:G,AP,K$	.341	.077
$R^2S:G,AN,C$	.202	.084
$R^2E:G,S,AP$	.177	.059
$R^2S:G,AP,K$	.214	.084
$R^2S:G,AN,K$	.204	.083
$R^2E:G,S,C$	.178	.060
$R^2E:G,S,K$	.181	.055
$R^2C:G,K - R^2C:G$	.073	.033
$R^2AP:G,C - R^2AP:G$	.170	.074
$R^2AN:G,AP - R^2AN:G$	.157	.055
$R^2S:G,AP - R^2S:G$	.060	.044
$R^2S:G,AN - R^2S:G$	.039	.031
$R^2E:G,S - R^2E:G$	.039	.028
$R^2AP:G,C,K - R^2AP:G,C$	.023	.016
$R^2AN:G,AP,C - R^2AN:G,AP$	.049	.028
$R^2S:G,AP,C - R^2S:G,AP$	.017	.013
$R^2S:G,AN,AP - R^2S:G,AN$	.032	.025
$R^2E:G,S,AN - R^2E:G,S$	.012	.011
$R^2AN:G,AP,K - R^2AN:G,AP$	.006	.007
$R^2S:G,AN,C - R^2S:G,AN$	.029	.025
$R^2E:G,S,AP - R^2E:G,S$	.021	.015
$R^2E:G,S,C - R^2E:G,S$	.022	.020
$R^2S:G,AP,K - R^2S:G,AP$	.020	.015
$R^2S:G,AN,K - R^2S:G,AN$	.030	.021
$R^2E:G,S,K - R^2E:G,S$	.025	.020

Table 7

Proportions of Variance for Direct and Indirect Causal Links for Figure 7: Grade 9 across Contents

Grade 9 (N = 303)

Proportion of Variance	Atomic Struc.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2C:K	.134	.147	.300	.219	.200	.066
R^2AP:C	.240	.275	.360	.444	.330	.079
R^2AN:AP	.187	.328	.325	.302	.285	.058
R^2S:AP	.061	.066	.196	.134	.114	.055
R^2S:AN	.010	.038	.206	.058	.078	.076
R^2E:S	.084	.036	.120	.092	.083	.030
R^2AP:C,K	.276	.330	.427	.480	.378	.080
R^2AN:AP,C	.275	.378	.375	.379	.352	.044
R^2S:AP,C	.070	.069	.265	.190	.148	.083
R^2S:AN,AP	.061	.069	.256	.136	.130	.078
R^2E:S,AN	.091	.070	.154	.174	.122	.043
R^2AN:AP,K	.192	.328	.363	.303	.296	.064
R^2S:AN,C	.042	.048	.284	.176	.137	.100
R^2E:S,AP	.152	.122	.183	.192	.162	.028
R^2S:AP,K	.087	.066	.259	.206	.154	.081
R^2S:AN,K	.064	.041	.278	.187	.142	.096
R^2E:S,C	.115	.111	.158	.231	.154	.048
R^2E:S,K	.144	.170	.151	.122	.147	.017
R^2AP:C,K - R^2AP:C	.036	.055	.067	.036	.048	.013
R^2AN:AP,C - R^2AN:AP	.088	.050	.050	.077	.066	.017
R^2S:AN,AP - R^2S:AN	.051	.031	.050	.078	.052	.017
R^2E:S,AN - R^2E:S	.007	.034	.034	.082	.039	.027
R^2AN:AP,K - R^2AN:AP	.005	.000	.038	.001	.011	.016
R^2S:AP,C - R^2S:AP	.009	.003	.069	.056	.034	.029
R^2S:AN,C - R^2S:AN	.032	.010	.078	.118	.059	.042
R^2E:S,AP - R^2E:S	.068	.086	.063	.100	.079	.015
R^2E:S,C - R^2E:S	.031	.075	.038	.139	.071	.043
R^2S:AP,K - R^2S:AP	.026	.000	.063	.072	.040	.029
R^2S:AN,K R^2S:AN	.054	.003	.072	.129	.064	.045
R^2E:S,K - R^2E:S	.060	.134	.031	.030	.064	.042

Table 8

Proportions of Variance for Direct and Indirect Causal Links for Figure 9: Grade 10 across Contents

Grade 10 (N = 276)

Proportion of Variance	Atomic Struc.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2C:K	.255	.229	.355	.254	.273	.048
R^2AP:C	.305	.378	.424	.516	.406	.076
R^2AN:AP	.165	.347	.354	.302	.292	.076
R^2S:AP	.098	.122	.288	.159	.167	.073
R^2S:AN	.119	.051	.173	.083	.106	.045
R^2E:S	.104	.042	.160	.116	.105	.042
R^2AP:C,K	.362	.444	.476	.527	.452	.060
R^2AN:AP,C	.284	.358	.418	.357	.354	.047
R^2S:AP,C	.114	.129	.326	.215	.196	.084
R^2S:AN,AP	.155	.123	.303	.166	.187	.069
R^2E:S,AN	.147	.115	.173	.196	.158	.030
R^2AN:AP,K	.197	.352	.370	.306	.306	.067
R^2S:AN,C	.133	.091	.272	.205	.175	.069
R^2E:S,AP	.148	.158	.199	.209	.178	.026
R^2S:AP,K	.148	.128	.325	.194	.199	.077
R^2S:AN,K	.177	.082	.271	.157	.172	.067
R^2E:S,C	.116	.186	.177	.224	.176	.039
R^2E:S,K	.217	.224	.177	.168	.196	.024
R^2AP:C,K - R^2AP:C	.057	.066	.052	.011	.046	.021
R^2AN:AP,C - R^2AN:AP	.119	.011	.064	.055	.062	.038
R^2S:AN,AP - R^2S:AN	.036	.072	.130	.083	.080	.034
R^2E:S,AN - R^2E:S	.043	.073	.013	.080	.052	.027
R^2AN:AP,K - R^2AN:AP	.032	.005	.016	.004	.014	.011
R^2S:AP,C - R^2S:AP	.016	.007	.038	.056	.029	.019
R^2S:AN,C - R^2S:AN	.014	.040	.099	.122	.069	.044
R^2E:S,AP - R^2E:S	.044	.116	.039	.093	.073	.033
R^2E:S,C - R^2E:S	.012	.144	.017	.108	.070	.057
R^2S:AP,K - R^2S:AP	.050	.006	.037	.035	.032	.016
R^2S:AN,K - R^2S:AN	.058	.031	.098	.074	.065	.024
R^2E:S,K - R^2E:S	.113	.182	.017	.052	.091	.063

Table 9.

Proportions of Variance for Direct and Indirect Causal Links for Figure 11: Grade 11 across Contents

Grade 11 (N = 282)

Proportion of Variance	Atomic Struct.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
$R^2C:K$	.202	.267	.261	.263	.248	.027
$R^2AP:C$	.465	.370	.426	.494	.439	.046
$R^2AN:AP$	.446	.266	.449	.340	.375	.077
$R^2S:AP$	.059	.164	.282	.268	.193	.090
$R^2S:AN$	.062	.117	.225	.145	.137	.059
$R^2E:S$	.112	.014	.065	.141	.083	.048
$R^2AP:C,K$	.487	.438	.485	.518	.482	.029
$R^2AN:AP,C$	.485	.322	.477	.383	.417	.068
$R^2S:AP,C$	.095	.210	.315	.306	.231	.089
$R^2S:AN,AP$	.073	.118	.307	.278	.194	.100
$R^2E:S,AN$	.118	.072	.079	.169	.109	.039
$R^2AN:AP,K$	.447	.274	.470	.340	.383	.080
$R^2S:AN,C$	.100	.198	.294	.267	.215	.075
$R^2E:S,AP$	.120	.151	.077	.220	.142	.052
$R^2S:AP,K$	.105	.166	.322	.276	.217	.086
$R^2S:AN,K$	.116	.137	.292	.198	.186	.068
$R^2E:S,C$	.125	.102	.072	.219	.129	.055
$R^2E:S,K$	.165	.135	.078	.184	.140	.040
$R^2AP:C,K - R^2AP:C$	.022	.068	.059	.024	.043	.021
$R^2AN:AP,C - R^2AN:AP$	.039	.056	.028	.043	.041	.010
$R^2S:AN,AP - R^2S:AN$	.011	.001	.082	.133.	.057	.054
$R^2E:S,AN - R^2E:S$	.006	.058	.014	.028	.026	.020
$R^2AN:AP,K - R^2AN:AP$	.001	.008	.021	.000	.007	.008
$R^2S:AP,C - R^2S:AP$	.036	.046	.033	.038	.038	.004
$R^2S:AN,C - R^2S:AN$	.038	.081	.069	.122	.077	.030
$R^2E:S,AP - R^2E:S$	.008	.137	.012	.079	.059	.053
$R^2E:S,C - R^2E:S$	.013	.088	.007	.078	.046	.037
$R^2S:AP,K - R^2S:AP$	.046	.002	.040	.008	.024	.019
$R^2S:AN,K - R^2S:AN$	.054	.020	.067	.053	.048	.017
$R^2E:S,K - R^2E:S$	.053	.121	.013	.043	.057	.040

Table 10

Proportions of Variance for Direct and Indirect Causal Links for Figure 13: Grade 12 across Contents

Grade 12 (N = 267)

Proportion of Variance	Atomic Struct.	Glaciers	Earth quake	Econ. Growth	Mean	Sample St. Dev.
$R^2C:K$	.141	.125	.197	.066	.132	.047
$R^2AP:C$	.342	.377	.438	.477	.408	.052
$R^2AN:AP$	.210	.222	.366	.301	.275	.063
$R^2S:AP$	.121	.092	.168	.174	.139	.034
$R^2S:AN$	.088	.077	.179	.097	.110	.040
$R^2E:S$	.078	.041	.077	.086	.070	.017
$R^2AP:C,K$	.380	.403	.502	.486	.443	.052
$R^2AN:AP,C$	.294	.295	.440	.429	.364	.070
$R^2S:AP,C$	.143	.136	.181	.176	.159	.020
$R^2S:AN,AP$	.145	.116	.216	.184	.165	.038
$R^2E:S,AN$	.081	.092	.091	.118	.095	.014
$R^2AN:AP,K$	.210	.222	.376	.302	.277	.067
$R^2S:AN,C$	.129	.138	.195	.123	.146	.029
$R^2E:S,AP$	.095	.072	.077	.117	.090	.018
$R^2S:AP,K$	.169	.103	.220	.222	.178	.048
$R^2S:AN,K$	.174	.102	.247	.178	.175	.051
$R^2E:S,C$	.120	.065	.077	.150	.103	.034
$R^2E:S,K$	.113	.075	.096	.110	.098	.015
$R^2AP:C,K - R^2AP:C$	.038	.026	.064	.009	.034	.020
$R^2AN:AP,C - R^2AN:AP$	.084	.073	.074	.128	.090	.022
$R^2S:AN,AP - R^2S:AN$	.057	.039	.037	.087	.055	.020
$R^2E:S,AN - R^2E:S$	.003	.051	.014	.032	.025	.018
$R^2AN:AP,K - R^2AN:AP$	.000	.000	.010	.001	.003	.004
$R^2S:AP,C - R^2S:AP$	.022	.044	.013	.002	.020	.015
$R^2S:AN,C - R^2S:AN$	.041	.061	.016	.026	.036	.017
$R^2E:S,AP - R^2E:S$	.017	.031	.000	.031	.020	.013
$R^2E:S,C - R^2E:S$	.042	.024	.000	.064	.032	.024
$R^2S:AP,K - R^2S:AP$	.048	.011	.052	.048	.040	.017
$R^2S:AN,K - R^2S:AN$	.086	.025	.068	.081	.065	.024
$R^2E:S,K - R^2E:S$	.035	.034	.019	.024	.028	.007

Table 11

Proportions of Variance for Direct and Indirect Causal Links for Figure 15: Atomic Structure across Grades

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
R^2C:K	.134	.255	.202	.141	.183	.049
R^2AP:C	.240	.305	.465	.342	.338	.082
R^2AN:AP	.187	.165	.446	.210	.252	.113
R^2S:AP	.061	.098	.059	.121	.085	.026
R^2S:AN	.010	.119	.062	.088	.070	.040
R^2E:S	.084	.104	.112	.078	.094	.014
R^2AP:C,K	.276	.362	.487	.380	.376	.075
R^2AN:AP,C	.275	.284	.485	.294	.334	.087
R^2S:AP,C	.070.	.114	.095	.143	.105	.027
R^2S:AN,AP	.061	.155	.073	.145	.108	.042
R^2E:S,AN	.091	.147	.118	.081	.109	.026
R^2AN:AP,K	.192	.197	.447	.210	.261	.107
R^2S:AN,C	.042	.133	.100	.129	.101	.036
R^2E:S,AP	.152	.148	.120	.095	.129	.023
R^2S:AP,K	.087	.148	.105	.169	.127	.033
R^2S:AN,K	.064	.177	.116	.174	.133	.047
R^2E:S,C	.115	.116	.125	.120	.119	.004
R^2E:S,K	.144	.217	.165	.113	.160	.038
R^2AP:C,K - R^2AP:C	.036	.057	.022	.038	.038	.012
R^2AN:AP,C - R^2AN:AP	.088	.119	.039	.084	.082	.029
R^2S:AN,AP - R^2S:AN	.051	.036	.011	.057	.039	.018
R^2E:S,AN - R^2E:S	.007	.043	.006	.003	.015	.016
R^2AN:AP,K - R^2AN:AP	.005	.032	.001	.000	.009	.013
R^2S:AP,C - R^2S:AP	.009	.016	.036	.022	.021	.010
R^2S:AN,C - R^2S:AN	.032	.014	.038	.041	.031	.010
R^2E:S,AP - R^2E:S	.068	.044	.008	.017	.034	.024
R^2E:S,C - R^2E:S	.031	.012	.013	.042	.024	.013
R^2S:AP,K - R^2S:AP	.026	.050	.046	.048	.042	.010
R^2S:AN,K - R^2S:AN	.054	.058	.054	.086	.063	.013
R^2E:S,K - R^2E:S	.060	.113	.053	.035	.065	.029

Table 12

Proportions of Variance for Direct and Indirect Causal Links for Figure 17: Glaciers across Grades

Glaciers

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample St. Dev.
R^2C:K	.147	.229	.267	.125	.192	.058
R^2AP:C	.275	.378	.370	.377	.350	.043
R^2AN:AP	.328	.347	.266	.222	.291	.050
R^2S:AP	.066	.122	.164	.092	.111	.036
R^2S:AN	.038	.051	.117	.077	.071	.030
R^2E:S	.036	.042	.014	.041	.033	.011
R^2AP:C,K	.330	.444	.438	.403	.404	.045
R^2AN:AP,C	.378	.358	.322	.295	.338	.032
R^2S:AP,C	.069	.129	.210	.136	.136	.050
R^2S:AN,AP	.069	.123	.118	.116	.106	.022
R^2E:S,AN	.070	.115	.072	.092	.087	.018
R^2AN:AP,K	.328	.352	.274	.222	.294	.050
R^2S:AN,C	.048	.091	.198	.138	.119	.056
R^2E:S,AP	.122	.158	.151	.072	.126	.034
R^2S:AP,K	.066	.128	.166	.103	.116	.036
R^2S:AN,K	.041	.082	.137	.102	.090	.035
R^2E:S,C	.111	.186	.102	.065	.116	.044
R^2E:S,K	.170	.224	.135	.075	.151	.054
R^2AP:C,K - R^2AP:C	.055	.066	.068	.026	.054	.017
R^2AN:AP,C - R^2AN:AP	.050	.011	.056	.073	.047	.023
R^2S:AN,AP - R^2S:AN	.031	.072	.001	.039	.036	.025
R^2E:S,AN - R^2E:S	.034	.073	.058	.051	.054	.014
R^2AN:AP,K - R^2AN:AP	.000	.005	.008	.000	.003	.003
R^2S:AP,C - R^2S:AP	.003	.007	.046	.044	.025	.020
R^2S:AN,C - R^2S:AN	.010	.040	.081	.061	.048	.026
R^2E:S,AP - R^2E:S	.086	.116	.137	.031	.092	.040
R^2E:S,C - R^2E:S	.075	.144	.088	.024	.083	.043
R^2S:AP,K - R^2S:AP	.000	.006	.002	.011	.005	.004
R^2S:AN,K - R^2S:AN	.003	.031	.020	.025	.020	.010
R^2E:S,K - R^2E:S	.134	.182	.121	.034	.118	.053

Table 13

Proportions of Variance for Direct and Indirect Causal Links for Figure 19: Earthquake across Contents

Earthquake

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample St. Dev.
R^2C:K	.300	.355	.261	.197	.278	.058
R^2AP:C	.360	.424	.426	.438	.412	.030
R^2AN:AP	.325	.354	.449	.366	.373	.046
R^2S:AP	.196	.288	.282	.168	.233	.052
R^2S:AN	.206	.173	.225	.179	.196	.021
R^2E:S	.120	.160	.065	.077	.105	.038
R^2AP:C,K	.427	.476	.485	.502	.472	.028
R^2AN:AP,C	.375	.418	.477	.440	.427	.037
R^2S:AP,C	.265	.326	.315	.181	.272	.057
R^2S:AN,AP	.256	.303	.307	.216	.270	.037
R^2E:S,AN	.154	.173	.079	.091	.124	.040
R^2AN:AP,K	.363	.370	.470	.376	.395	.044
R^2S:AN,C	.284	.272	.294	.195	.261	.039
R^2E:S,AP	.183	.199	.077	.077	.134	.057
R^2S:AP,K	.259	.325	.322	.220	.281	.044
R^2S:AN,K	.278	.271	.292	.247	.272	.016
R^2E:S,C	.158	.177	.072	.077	.121	.047
R^2E:S,K	.151	.177	.078	.096	.125	.040
R^2AP: C,K - R^2AP:C	.067	.052	.059	.064	.060	.006
R^2AN:AP,C - R^2AN:AP	.050	.064	.028	.074	.054	.017
R^2S:AN,AP - R^2S:AN	.050	.130	.082	.037	.075	.036
R^2E:S,AN - R^2E:S	.034	.013	.014	.014	.019	.009
R^2AN:AP,K - R^2AN:AP	.038	.016	.021	.010	.021	.010
R^2S:AP,C - R^2S:AP	.069	.038	.033	.013	.038	.020
R^2S:AN,C - R^2S:AN	.078	.099	.069	.016	.065	.031
R^2E:S,AP - R^2E:S	.063	.039	.012	.000	.028	.024
R^2E:S,C - R^2E:S	.038	.017	.007	.000	.015	.014
R^2S:AP,K - R^2S:AP	.063	.037	.040	.052	.048	.010
R^2S:AN,K - R^2S:AN	.072	.098	.067	.068	.076	.013
R^2E:S,K - R^2E:S	.031	.017	.013	.019	.020	.007

Table 14

Proportions of Variance for Direct and Indirect
Causal Links for Figure 21: Econ. Growth across Grades

Econ. Growth

Proportions of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
R^2C:K	.219	.254	.263	.066	.200	.079
R^2AP:C	.444	.516	.494	.477	.483	.026
R^2AN:AP	.302	.302	.340	.301	.311	.017
R^2S:AP	.134	.159	.268	.174	.184	.051
R^2S:AN	.058	.083	.145	.097	.096	.032
R^2E:S	.092	.116	.141	.086	.109	.022
R^2AP:C,K	.480	.527	.518	.486	.503	.020
R^2AN:AP,C	.379	.357	.383	.429	.387	.026
R^2S:AP,C	.190	.215	.306	.176	.222	.051
R^2S:AN,AP	.136	.166	.278	.184	.191	.053
R^2E:S,AN	.174	.196	.169	.118	.164	.029
R^2AN:AP,K	.303	.306	.340	.302	.313	.016
R^2S:AN,C	.176	.205	.267	.123	.193	.052
R^2E:S,AP	.192	.209	.220	.117	.184	.040
R^2S:AP,K	.206	.194	.276	.222	.224	.031
R^2S:AN,K	.187	.157	.198	.178	.180	.015
R^2E:S,C	.231	.224	.219	.150	.206	.033
R^2E:S,K	.122	.168	.184	.110	.146	.031
R^2AP:C,K-R^2AP:C	.036	.011	.024	.009	.020	.011
R^2AN:AP,C-R^2AN:AP	.077	.055	.043	.128	.076	.033
R^2S:AN,AP-R^2S:AN	.078	.083	.133	.087	.095	.022
R^2E:S,AN-R^2E:S	.082	.080	.028	.032	.055	.026
R^2AN:AP,K-R^2AN:AP	.001	.004	.000	.001	.001	.001
R^2S:AP,C-R^2S:AP	.056	.056	.038	.002	.038	.022
R^2S:AN,C -R^2S:AN	.118	.122	.122	.026	.097	.041
R^2E:S,AP-R^2E:S	.100	.093	.079	.031	.076	.027
R^2E:S,C-R^2E:S	.139	.108	.078	.064	.097	.029
R^2S:AP,K-R^2S:AP	.072	.035	.008	.048	.041	.023
R^2S:AN,K-R^2S:AN	.129	.074	.053	.081	.084	.028
R^2E:S,K-R^2E:S	.030	.052	.043	.024	.037	.001

Table 15

Proportions of Variance for Direct and Indirect Causal Links with G-Factor for Figure 8: Grade 9 across Contents

Grade 9 (N=303)

Proportion of Variance	Atomic Struct.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
$R^2K:G$	.233	.262	.197	.254	.236	.025
$R^2C:G$	.181	.237	.295	.262	.244	.042
$R^2AP:G$	.195	.199	.244	.274	.228	.033
$R^2AN:G$	.113	.214	.201	.129	.164	.044
$R^2S:G$	.073	.045	.276	.180	.143	.092
$R^2E:G$	.087	.187	.191	.199	.166	.046
$R^2C:G,K$	.214	.261	.412	.321	.302	.074
$R^2AP:G,C$	.307	.322	.400	.488	.379	.072
$R^2AN:G,AP$	.213	.382	.362	.310	.317	.065
$R^2S:G,AP$	.093	.078	.320	.208	.175	.098
$R^2S:G,AN$	.073	.057	.336	.189	.164	.112
$R^2E:G,S$	.13-	.197	.210	.215	.189	.032
$R^2AP:G,C,K$	.316	.349	.450	.504	.405	.076
$R^2AN:G,AP,C$	.282	.406	.389	.379	.364	.048
$R^2S:G,AP,C$	.095	.078	.342	.238	.188	.108
$R^2S:G,AN,AP$	.095	.079	.348	.209	.183	.108
$R^2E:G,S,AN$	.135	.197	.221	.252	.201	.043
$R^2AN:G,AP,K$	.234	.390	.385	.310	.330	.064
$R^2S:G,AN,C$	.084	.060	.357	.236	.184	.120
$R^2E:G,S,AP$	.169	.216	.235	.248	.217	.030
$R^2S:G,AP,K$	.103	.080	.350	.243	.194	.110
$R^2S:G,AN,K$	.089	.057	.365	.237	.197	.123
$R^2E:G,S,C,$	.144	.206	.217	.279	.211	.048
$R^2E:G,S,K$	.161	.233	.219	.216	.207	.027
$R^2C:G,K - R^2C:G$	.033	.024	.117	.059	.058	.036
$R^2C:G,K - R^2AP:G$	.112	.123	.156	.214	.151	.040
$R^2AN:G,AP - R^2AN:G$	.100	.168	.161	.181	.152	.031
$R^2S:G,AP - R^2S:G$	.020	.033	.044	.028	.031	.009
$R^2S:G,AN - R^2S:G$	.000	.012	.060	.009	.020	.023
$R^2E:G,S - R^2E:G$	.047	.010	.019	.016	.023	.014
$R^2AP:G,C,K - R^2AP:G,C$	.009	.027	.050	.016	.025	.016
$R^2AN:G,AP,C - R^2AN:G,AP$	.069	.024	.027	.069	.047	.022
$R^2S:G,AP,C - R^2S:G,AP$	.002	.000	.022	.030	.013	.013
$R^2S:G,AN,AP - R^2S:G,AN.$	.022	.022	.012	.020	.019	.004
$R^2E:G,S,AN - R^2E:G,S$	.001	.000	.011	.037	.012	.015
$R^2AN:G,AP,K - R^2AN:G,AP$	.021	.008	.023	.000	.013	.009
$R^2S:G,AN,C - R^2S:G,AN$	.011	.003	.021	.047	.020	.017
$R^2E:G,S,AP - R^2E:G,S$	.035	.019	.025	.033	.028	.006
$R^2E:G,S,C - R^2E:G,S$	.010	.009	.007	.064	.022	.024
$R^2S:G,AP,K - R^2S:G,AP$	.010	.002	.030	.035	.019	.014
$R^2S:G,AN,K - R^2S:G,AN$	.016	.000	.029	.048	.023	.018
$R^2E:G,S,K - R^2E:G,S$	.027	.036	.009	.001	.018	.014

Table 16

Proportions of Variance for Direct and Indirect
Causal Links with G-Factor for Figure 10: Grade 10 across Contents

Grade 10 (N=276)

Proportion of Variance	Atomic Struct.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2K:G	.331	.298	.248	.204	.270	.048
R^2C:G	.204	.306	.353	.275	.284	.054
R^2AP:G	.305	.401	.327	.232	.316	.060
R^2AN:G	.172	.200	.260	.202	.208	.032
R^2S:G	.151	.138	.258	.112	.165	.056
R^2E:G	.207	.168	.091	.193	.165	.045
R^2C:G,K	.294	.350	.473	.364	.370	.065
R^2AP:G,C	.420	.502	.477	.531	.482	.041
R^2AN:G,AP	.217	.356	.347	.347	.329	.067
R^2S:G,AP	.165	.160	.348	.186	.215	.078
R^2S:G,AN	.192	.143	.291	.136	.190	.062
R^2E:G,S	.232	.171	.173	.235	.203	.031
R^2AP:G,C,K	.429	.519	.510	.537	.499	.041
R^2AN:G,AP,C	.309	.363	.433	.379	.371	.044
R^2S:G,AP,C	.171	.161	.361	.225	.229	.080
R^2S:G,AN,AP	.197	.160	.352	.188	.224	.075
R^2E:G,S,AN	.241	.190	.179	.261	.218	.034
R^2AN:G,AP,K	.226	.358	.403	.347	.333	.066
R^2S:G,AN,C	.193	.148	.326	.217	.221	.065
R^2E:G,S,AP	.233	.198	.201	.268	.225	.028
R^2S:G,AP,K	.181	.160	.366	.206	.228	.081
R^2S:G,AN,K	.207	.145	.333	.176	.215	.071
R^2E:G,S,C	.233	.224	.181	.273	.228	.033
R^2E:G,S,K	.264	.252	.182	.246	.236	.032
R^2C:G,K - R^2C:G	.090	.044	.120	.089	.086	.027
R^2AP:G,C - R^2AP:G	.115	.101	.150	.299	.166	.079
R^2AN:G,AP - R^2AN:G	.045	.156	.137	.145	.121	.044
R^2S:G,AP - R^2S:G	.014	.022	.090	.074	.050	.033
R^2S:G,AN - R^2S:G	.041	.005	.033	.024	.026	.013
R^2E:G,S - R^2E:G	.025	.003	.082	.042	.038	.029
R^2AP:G,C,K - R^2AP:G,C	.009	.017	.033	.006	.016	.010
R^2AN:G,AP,C - R^2AN:G,AP	.092	.007	.036	.032	.042	.031
R^2S:G,AP,C - R^2S:G,AP	.006	.001	.013	.039	.015	.015
R^2S:G,AN,AP - R^2S:G,AN	.005	.017	.061	.052	.034	.023
R^2E:G,S,AN - R^2E:G,S	.009	.019	.006	.026	.015	.008
R^2AN:G,AP,K - R^2AN:G,AP	.009	.002	.006	.000	.004	.003
R^2S:G,AN,C - R^2S:G,AN	.001	.005	.035	.081	.030	.032
R^2E:G,S,AP - R^2E:G,S	.001	.027	.028	.033	.022	.012
R^2E:G,S,C,-R^2E:G,S	.001	.053	.008	.038	.025	.021
R^2S:G,AP,K - R^2S:G,AP	.016	.000	.018	.020	.013	.008
R^2S:G,AN,K - R^2S:G,AN	.015	.002	.042	.040	.025	.017
R^2E:G,S,K - R^2E:G,S	.032	.081	.009	.011	.033	.029

Table 17

Proportions of Variance for Direct and Indirect Causal Links with G-Factor for Figure 12: Grade 11 across Contents

Grade 11 (N=282)

Proportion of Variance	Atomic Struct.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
R^2K:G	.180	.196	.195	.129	.175	.027
R^2C:G	.178	.346	.246	.277	.262	.060
R^2AP:G	.277	.348	.321	.317	.316	.025
R^2AN:G	.201	.240	.234	.150	.206	.036
R^2S:G	.091	.193	.208	.098	.147	.053
R^2E:G	.043	.140	.107	.112	.100	.035
R^2C:G,K	.267	.428	.352	.397	.361	.061
R^2AP:G,C	.534	.452	.505	.546	.509	.036
R^2AN:G,AP	.459	.319	.465	.345	.397	.066
R^2S:G,AP	.101	.225	.317	.269	.228	.080
R^2S:G,AN	.107	.214	.292	.177	.197	.067
R^2E:G,S	.124	.142	.121	.193	.145	.029
R^2AP:G,C,K	.540	.495	.536	.562	.533	.024
R^2AN:G,AP,C	.494	.346	.486	.383	.427	.064
R^2S:G,AP,C	.130	.244	.339	.306	.255	.080
R^2S:G,AN,AP	.108	.234	.334	.278	.238	.083
R^2E:G,S,AN	.125	.153	.123	.204	.151	.033
R^2AN:G,AP,K	.459	.321	.480	.345	.401	.069
R^2S:G,AN,C	.130	.239	.329	.269	.242	.072
R^2E:G,S,AP	.126	.191	.121	.231	.167	.046
R^2S:G,AP,K	.129	.225	.346	.276	.244	.079
R^2S:G,AN,K	.136	.216	.330	.213	.224	.069
R^2E:G,S,C	.131	.161	.121	.232	.161	.043
R^2E:G,S,K	.166	.194	.123	.216	.175	.035
R^2C:G,K - R^2C:G	.089	.082	.106	.120	.099	.015
R^2AP:G,C, - R^2AP:G	.257	.104	.184	.229	.193	.058
R^2AN:G,AP - R^2AN:G	.258	.079	.231	.195	.191	.068
R^2S:G,AP - R^2S:G	.010	.032	.109	.171	.080	.064
R^2S:G,AN - R^2S:G	.016	.021	.084	.079	.050	.032
R^2E:G,S - R^2E:G	.081	.002	.014	.081	.044	.037
R^2AP:G,C,K - R^2AP:G,C	.006	.043	.031	.016	.024	.014
R^2AN:G,AP,C-R^2AN:G,AP	.035	.027	.021	.038	.030	.007
R^2S:G,AP,C-R^2S:G,AP	.029	.019	.022	.037	.027	.007
R^2S:G,AN,AP-R^2S:G,AN	.001	.020	.042	.101	.041	.038
R^2E:G;S,AN - R^2:G,S	.001	.011	.002	.011	.006	.005
R^2AN:G,AP,K-R^2AN:G,AP	.000	.002	.015	.000	.004	.006
R^2S:G,AN,C-R^2S:G,AN	.023	.025	.037	.092	.044	.028
R^2E:G,S,AP-R^2E:G,S	.002	.049	.000	.038	.022	.022
R^2E:G,S,C - R^2E:G,S	.007	.019	.000	.039	.016	.015
R^2S:G,AP,K-R^2S:G,AP	.028	.000	.029	.007	.016	.013
R^2S:G,AN,K-R^2S:G,AN	.029	.002	.038	.036	.026	.014
R^2E:G,S,K - R^2E:G,S	.042	.052	.002	.023	.030	.019

Table 18

Proportions of Variance for Direct and Indirect Causal Links with G-Factor for Figure 14: Grade 12 across Contents

Grade 12 (N=267)

Proportion of Variance	Atomic Struct.	Glaciers	Earth quake	Econ. Growth	Mean	Sample Stan. Dev.
$R^2K:G$	.092	.163	.247	.046	.137	.076
$R^2C:G$	.138	.242	.215	.232	.207	.041
$R^2AP:G$	.197	.212	.444	.243	.274	.100
$R^2AN:G$	.122	.087	.161	.158	.132	.030
$R^2S:G$	.087	.087	.079	.070	.081	.007
$R^2E:G$	.028	.061	.030	.042	.040	.013
$R^2C:G,K$	.215	.270	.276	.257	.254	.024
$R^2AP:G,C$	.402	.410	.445	.511	.442	.043
$R^2AN:G,AP$	.236	.230	.400	.322	.297	.070
$R^2S:G,AP$	.146	.123	.186	.179	.158	.025
$R^2S:G,AN$	.130	.127	.194	.120	.143	.030
$R^2E:G,S$	.086	.079	.087	.104	.089	.009
$R^2AP:G,C,K$	.424	.423	.503	.516	.466	.043
$R^2AN:G,AP,C$	.309	.295	.451	.434	.372	.071
$R^2S:G,AP,C$	.161	.150	.192	.180	.171	.016
$R^2S:G,AN,AP$	.162	.141	.224	.186	.178	.031
$R^2E:G,S,AN$	.087	.114	.096	.123	.105	.014
$R^2AN:G,AP,K$	.238	.230	.401	.323	.298	.070
$R^2S:G,AN,C$	.155	.155	.203	.134	.162	.025
$R^2E:G,S,AP$	.097	.091	.090	.121	.100	.013
$R^2S:G,AP,K$	.184	.126	.223	.225	.189	.040
$R^2S:G,AN,K$	.192	.133	.248	.189	.190	.041
$R^2E:G,S,C$	.121	.085	.089	.151	.111	.027
$R^2E:G,S,K$	.115	.094	.098	.122	.107	.012
$R^2C:G,K-R^2C:G$	.077	.028	.061	.025	.048	.022
$R^2AP:G,C-R^2AP:G$	.205	.198	.001	.268	.168	.100
$R^2AN:G,AP-R^2AN:G$	.114	.143	.239	.164	.165	.046
$R^2S:G,AP-R^2S:G$	.059	.036	.107	.109	.078	.031
$R^2S:G,AN-R^2S:G$	.043	.040	.115	.050	.062	.031
$R^2E:G,S-R^2E:G$	.058	.018	.057	.062	.049	.018
$R^2AP:G,C,K-R^2AP:G,C$	.022	.013	.058	.005	.024	.020
$R^2AN:G,AP,C-R^2AN:G,AP$	.073	.065	.051	.112	.075	.023
$R^2S:G,AP,C-R^2S:G,AP$	.015	.027	.006	.001	.012	.010
$R^2S:G,AN,AP-R^2S:G,AN$	.032	.014	.030	.066	.035	.019
$R^2E:G,S,AN - R^2E:G,S$	.001	.035	.009	.019	.016	.013
$R^2AN:G,AP,K-R^2AN:G,AP$	.002	.000	.001	.001	.001	.001
$R^2S:G,AN,C-R^2S:G,AN$	.025	.028	.009	.014	.019	.008
$R^2E:G,S,AP-R^2E:G,S$	.011	.012	.003	.017	.011	.005
$R^2E:G,S,C - R^2E:G,S$	.035	.006	.002	.047	.022	.019
$R^2S:G,AP,K-R^2S:G,AP$	.038	.003	.037	.046	.031	.017
$R^2S:G,AN,K-R^2S:G,AN$	.062	.006	.054	.069	.048	.025
$R^2E:G,S,K - R^2E:G,S$	.029	.015	.011	.018	.018	.007

Table 19

Proportions of Variance for Direct and Indirect Causal Links with g Factor for Figure 16: Atomic Structure across Grades

Atomic Structure

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267	Mean	Sample Stan. Dev.
R^2K:G	.233	.331	.180	.092	.209	.087
R^2C:G	.181	.204	.178	.138	.175	.024
R^2AP:G	.195	.305	.277	.197	.243	.049
R^2AN:G	.113	.172	.201	.122	.152	.036
R^2S:G	.073	.151	.091	.087	.100	.030
R^2E:G	.087	.207	.043	.028	.091	.070
R^2C:G,K	.214	.294	.267	.215	.247	.034
R^2AP:G,C	.307	.420	.534	.402	.416	.081
R^2AN:G,AP	.213	.217	.459	.236	.281	.103
R^2S:G,AP	.093	.165	.101	.146	.126	.030
R^2S:G,AN	.073	.192	.107	.130	.125	.043
R^2E:G,S	.134	.232	.124	.086	.144	.054
R^2AP:G,C,K	.316	.429	.540	.424	.427	.079
R^2AN:C,AP,C	.282	.309	.494	.309	.348	.085
R^2S:G,AP,C	.095	.171	.130	.161	.139	.030
R^2S:G,AN AP	.095	.197	.108	.162	.140	.041
R^2E:G,S,AN	.135	.241	.125	.087	.147	.057
R^2AN:G,AP,K	.234	.226	.459	.238	.289	.098
R^2S:G,AN,C	.084	.193	.130	.155	.140	.040
R^2E:G,S,AP	.169	.233	.126	.097	.156	.051
R^2S:G,AP,K	.103	.181	.129	.184	.149	.035
R^2S:G,AN,K	.089	.207	.136	.192	.156	.047
R^2E:G,S,C	.144	.233	.131	.121	.157	.044
R^2E:G,S,K	.161	.264	.166	.115	.176	.054
R^2C:G,K-R^2C:G	.033	.090	.089	.077	.072	.023
R^2AP:G,C,-R^2AP:G	.112	.115	.257	.205	.172	.062
R^2AN:G,AP-R^2AN:G	.100	.045	.258	.114	.129	.079
R^2S:G,AP-R^2S:G	.020	.014	.010	.059	.026	.020
R^2S:G,AN-R^2S:G	.000	.041	.016	.043	.025	.018
R^2E:G,S-R^2E:G	.047	.025	.081	.058	.053	.020
R^2AP:G,C,K-R^2AP:G,C	.009	.009	.006	.022	.011	.006
R^2AN:G,AP,C-R^2AN:G,AP	.069	.092	.035	.073	.067	.021
R^2S:G,AP,C-R^2S:G,AP	.002	.006	.029	.015	.013	.010
R^2S:G,AN,AP-R^2S:G,AN	.022	.005	.001	.032	.015	.013
R^2E:G,S,AN-R^2E:G,S	.001	.009	.001	.001	.003	.003
R^2AN:G,AP,K-R^2AN:G,AP	.021	.009	.000	.002	.008	.008
R^2S:G,AN,C-R^2S:G,AN	.011	.001	.023	.025	.015	.010
R^2E:G,S,AP-R^2E:G,S	.035	.001	.002	.011	.012	.014
R^2E:G,S,C-R^2E:G,S	.010	.001	.007	.035	.013	.013
R^2S:G,AP,K-R^2S:G,AP	.010	.016	.028	.038	.023	.011
R^2S:G,AN,K-R^2S:G,AN	.016	.015	.029	.062	.030	.019
R^2E:G,S,K-R^2E:G,S	.027	.032	.042	.029	.032	.006

Table 20

Proportions of Variance for Direct and Indirect Causal Links with G-Factor for Figure 18: Glaciers across Grades

Glaciers

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
R^2K:G	.262	.298	.196	.163	.230	.053
R^2C:G	.237	.306	.346	.242	.283	.046
R^2AP:G	.199	.401	.348	.212	.290	.087
R^2AN:G	.214	.200	.240	.087	.185	.059
R^2S:G	.045	.138	.193	.087	.116	.055
R^2E:G	.187	.168	.140	.061	.139	.048
R^2C:G,K	.261	.350	.428	.270	.327	.068
R^2AP:G,C	.322	.502	.452	.410	.421	.066
R^2AN:G,AP	.382	.356	.319	.230	.322	.058
R^2S:G,AP	.078	.160	.225	.123	.146	.054
R^2S:G,AN	.057	.143	.214	.127	.135	.056
R^2E:G,S	.197	.171	.142	.079	.147	.044
R^2AP:G,C,K	.349	.519	.495	.423	.446	.066
R^2AN:G,AP,C	.406	.363	.346	.295	.352	.040
R^2S:G,AP,C	.078	.161	.244	.150	.158	.059
R^2S:G,AN,AP	.079	.160	.234	.141	.153	.055
R^2E:G,S,AN	.197	.190	.153	.114	.163	.033
R^2AN:G,AP,K	.390	.358	.321	.230	.325	.060
R^2S:G,AN,C	.060	.148	.239	.155	.150	.063
R^2E:G,S,AP	.216	.198	.191	.091	.174	.049
R^2S:G,AP,K	.080	.160	.225	.126	.148	.053
R^2S:G,AN,K	.057	.145	.216	.133	.138	.056
R^2E:G,S,C	.206	.224	.161	.085	.169	.054
R^2E:G,S,K	.233	.252	.194	.094	.193	.061
R^2C:G,K - R^2C:G	.024	.044	.082	.028	.044	.023
R^2AP:G,C-R^2AP:G	.123	.101	.104	.198	.131	.039
R^2AN:G,AP-R^2AN:G	.168	.156	.079	.143	.136	.034
R^2S:G,AP-R^2S:G	.033	.022	.032	.036	.031	.005
R^2S:G,AN-R^2S:G	.012	.005	.021	.040	.019	.013
R^2E:G,S-R^2E:G	.010	.003	.002	.018	.008	.006
R^2AP:G,C,K-R^2AP:G,C	.027	.017	.043	.013	.025	.012
R^2AN:G,AP,C-R^2AN:G,AP	.024	.007	.027	.065	.031	.021
R^2S:G,AP,C-R^2S:G,AP	.000	.001	.019	.027	.012	.012
R^2S:G,AN,AP-R^2S:G,AN	.022	.017	.020	.014	.018	.003
R^2E:G,S,AN-R^2E:G,S	.000	.019	.011	.035	.016	.013
R^2AN:G,AP,K-R^2AN:G,AP	.008	.002	.002	.000	.003	.003
R^2S:G,AN,C-R^2S:G,AN	.003	.005	.025	.028	.015	.011
R^2E:G,S,AP-R^2E:G,S	.019	.027	.049	.012	.027	.014
R^2E:G,S,C-R^2E:G,S	.009	.053	.019	.006	.022	.019
R^2S:G,AP,K-R^2S:G,AP	.002	.000	.000	.003	.001	.001
R^2S:G,AN,K-R^2S:G,AN	.000	.002	.002	.006	.002	.002
R^2E:G,S,K-R^2E:G,S	.036	.081	.052	.015	.046	.024

Table 21

Proportions of Variance for Direct and Indirect Causal Links with G-Factor for Figure 20: Earthquake across Grades

Earthquake

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample Stan. Dev.
$R^2K:G$	.197	.248	.195	.247	.222	.026
$R^2C:G$	.295	.353	.246	.215	.277	.052
$R^2AP:G$	.244	.327	.321	.444	.334	.071
$R^2AN:G$	.201	.260	.234	.161	.214	.037
$R^2S:G$	.276	.258	.208	.079	.205	.077
$R^2E:G$	.191	.091	.107	.030	.105	.057
$R^2C:G,K$	.412	.473	.352	.276	.378	.073
$R^2AP:G,C$	.400	.477	.505	.445	.457	.039
$R^2AN:G,AP$	.362	.397	.465	.400	.406	.037
$R^2S:G,AP$	.320	.348	.317	.186	.293	.063
$R^2S:G,AN$	.336	.291	.292	.194	.278	.052
$R^2E:G,S$	.210	.173	.121	.087	.148	.047
$R^2AP:G,C,K$	.450	.510	.536	.503	.500	.031
$R^2AN:G,AP,C$	.389	.433	.486	.451	.440	.035
$R^2S:G,AP,C$	.342	.361	.339	.192	.308	.068
$R^2S:G,AN,AP$	.348	.352	.334	.224	.314	.053
$R^2E:G,S,AN$	.221	.179	.123	.096	.155	.049
$R^2AN:G,AP,K$	.385	.403	.480	.401	.417	.037
$R^2S:G,AN,C$	.357	.326	.329	.203	.304	.059
$R^2E:G,S,AP$	.235	.201	.121	.090	.162	.059
$R^2S:G,AP,K$	.350	.366	.346	.223	.321	.057
$R^2S:G,AN,K$	.365	.333	.330	.248	.319	.043
$R^2E:G,S,C$	.217	.181	.121	.089	.152	.050
$R^2E:G,S,K$	.219	.182	.123	.098	.155	.048
$R^2C:G,K-R^2C:G$	.117	.120	.106	.061	.101	.024
$R^2AP:G,C-R^2AP:G$	.156	.150	.184	.001	.123	.071
$R^2AN:G,AP-R^2AN:G$	.161	.137	.231	.239	.192	.044
$R^2S:G,AP-R^2S:G$	.044	.090	.109	.107	.087	.026
$R^2S:G,AN-R^2S:G$	.060	.033	.084	.115	.073	.030
$R^2E:G,S-R^2E:G$	.019	.082	.014	.057	.043	.028
$R^2AP:G,C,K-R^2AP:G,C$	.050	.033	.031	.058	.043	.011
$R^2AN:G,AP,C-R^2AN:G,AP$	.027	.036	.021	.051	.034	.011
$R^2S:G,AP,C-R^2S:G,AP$	.022	.013	.077	.006	.016	.007
$R^2S:G,AN,AP-R^2S:G,AN$	.012	.061	.042	.030	.036	.018
$R^2E:G,S,AN-R^2E:G,S$	.011	.006	.002	.009	.007	.003
$R^2AN:G,AP,K-R^2AN:G,AP$	.023	.006	.015	.001	.011	.008
$R^2S:G,AN,C-R^2S:G,AN$	.021	.035	.037	.009	.025	.011
$R^2E:G,S,AP-R^2E:G,S$	.025	.028	.000	.003	.014	.013
$R^2E:G,S,C-R^2E:G,S$	.007	.008	.000	.001	.004	.003
$R^2S:G,AP,K-R^2S:G,AP$	.030	.018	.029	.037	.028	.007
$R^2S:G,AN,K-R^2S:G,AN$	.029	.042	.038	.054	.041	.009
$R^2E:G,S,K-R^2E:G,S$	.009	.009	.002	.011	.008	.003

Table 22

Proportions of Variance for Direct and Indirect
Causal Links with G-Factor for Figure 22: Econ. Growth across Grades

Econ. Growth

Proportion of Variance	Grade 9 (N=303)	Grade 10 (N=276)	Grade 11 (N=282)	Grade 12 (N=267)	Mean	Sample St. Dev.
R^2K:G	.254	.204	.129	.046	.158	.079
R^2C:G	.262	.275	.277	.232	.261	.018
R^2AP:G	.274	.232	.317	.243	.266	.033
R^2AN:G	.129	.202	.150	.158	.160	.027
R^2S:G	.180	.112	.098	.070	.115	.040
R^2E:G	.199	.193	.112	.042	.136	.064
R^2C:G,K	.321	.364	.397	.257	.335	.052
R^2AP:G,C	.488	.531	.546	.511	.519	.022
R^2AN:G,AP	.310	.347	.345	.322	.331	.016
R^2S:G,AP	.208	.186	.269	.179	.210	.035
R^2S:G,AN	.189	.136	.177	.120	.155	.028
R^2E:G,S	.215	.235	.193	.104	.187	.050
R^2AP:G,C,K	.504	.537	.562	.516	.530	.022
R^2AN:G,AP,C	.379	.379	.383	.434	.394	.023
R^2S:G,AP,C	.238	.225	.306	.180	.237	.045
R^2S:G,AN,AP	.209	.188	.278	.186	.215	.037
R^2E:G,S,AN	.252	.261	.204	.123	.210	.055
R^2AN:G,AP,K	.310	.347	.345	.323	.331	.015
R^2S:G,AN,C	.236	.217	.269	.134	.214	.050
R^2E:G,S,AP	.248	.268	.231	.121	.217	.057
R^2S:G,AP,K	.243	.206	.276	.225	.237	.026
R^2S:G,AN,K	.237	.176	.213	.189	.204	.023
R^2E:G,S,C	.279	.273	.232	.151	.234	.051
R^2E:G,S,K	.216	.246	.216	.122	.200	.047
R^2C:G,K-R^2C:G	.059	.089	.120	.025	.073	.035
R^2AP:G,C-R^2AP:G	.214	.299	.229	.268	.252	.033
R^2AN:G,AP-R^2AN:G	.181	.145	.195	.164	.171	.019
R^2S:G,AP-R^2S:G	.028	.074	.171	.109	.095	.052
R^2S:G,AN-R^2S:G	.009	.024	.079	.050	.040	.027
R^2E:G,S-R^2E:G	.016	.042	.081	.062	.050	.024
R^2AP:G,C,K-R^2AP:G,C	.016	.006	.016	.005	.011	.005
R^2AN:G,AP,C-R^2AN:G,AP	.069	.032	.038	.112	.063	.032
R^2S:G,AP,C-R^2S:G,AP	.030	.039	.037	.001	.027	.015
R^2S:G,AN,AP-R^2S:G,AN	.020	.052	.101	.066	.060	.029
R^2E:G,S,AN-R^2E:G,S	.037	.026	.011	.019	.023	.010
R^2AN:G,AP,K-R^2AN:G,AP	.000	.000	.000	.001	.000	.000
R^2S:G,AN,C-R^2S:G,AN	.047	.081	.092	.014	.058	.031
R^2E:G,S,AP-R^2E:G,S	.033	.033	.038	.017	.030	.008
R^2E:G,S,C,-R^2E:G,S	.064	.038	.039	.047	.047	.010
R^2S:G,AP,K-R^2S:G,AP	.035	.020	.007	.046	.027	.015
R^2S:G,AN,K-R^2S:G,AN	.048	.040	.036	.069	.048	.013
R^2E:G,S,K-R^2E:G,S	.001	.011	.023	.018	.013	.008

TABLE 23

Means and Standard Deviations for Proportions of Variance for Direct and Indirect Causal Links for Total 16 Replications with the Assumed Hierarchical Order Compared to the Reversed Order for Synthesis and Evaluation

A. Assumed Hierarchical Structure from Analysis to Synthesis or Evaluation

Figure 1 Model:	Mean	Sample St.Dev.		Mean	Sample St.Dev.
R^2S:AN	.108	.061	R^2E:AN	.071	.035
R^2S:AN,AP	.169	.079	R^2E:AN,AP	.121	.053
R^2S:AN,C	.168	.079	R^2E:AN,C	.118	.059
R^2S:AN,K	.169	.074	R^2E:AN,K	.135	.047
R^2S:AN,AP - R^2S:AN	.061	.036	R^2E:AN,AP - R^2E:AN	.050	.031
R^2S:AN,C - R^2S:AN	.060	.038	R^2E:AN,C - R^2E:AN	.047	.034
R^2S:AN,K - R^2S:AN	.061	.030	R^2E:AN,K - R^2E:AN	.064	.036

Figure 2 Model:	Mean	Sample St.Dev.		Mean	Sample St.Dev.
R^2S:G	.134	.068	R^2E:G	.118	.064
R^2S:G,AN	.174	.077	R^2E:G,AN	.138	.066
R^2S:G,AN,AP	.206	.083	R^2E:G,AN,AP	.160	.069
R^2S:G,AN,C	.202	.084	R^2E:G,AN,C	.160	.070
R^2S:G,AN,K	.204	.083	R^2E:G,AN,K	.169	.063
R^2S:G,AN - R^2S:G	.039	.031	R^2E:G,AN - R^2E:G	.020	.015
R^2S:G,AN,AP - R^2S:G,AN	.032	.025	R^2E:G,AN,AP - R^2E:G,AN	.021	.018
R^2S:G,AN,C - R^2S:G,AN	.029	.025	R^2E:G,AN,C - R^2E:G,AN	.022	.019
R^2S:G,AN,K - R^2S:G,AN	.030	.021	R^2E:G,AN,K - R^2E:G,AN	.030	.020

B. Suggested Y-Shaped Structure from Application to Synthesis or Evaluation

Figure 1 Model:	Mean	Sample St.Dev.		Mean	Sample St.Dev.
R^2S:AP	.153	.073	R^2E:AP	.106	.054
R^2S:AP,C	.184	.082	R^2E:AP,C	.129	.066
R^2S:AP,K	.187	.078	R^2E:AP,K	.147	.055
R^2S:AP,C - R^2S:AP	.030	.020	R^2E:AP,C - R^2E:AP	.023	.020
R^2S:AP,K - R^2S:AP	.034	.022	R^2E:AP,K - R^2E:AP	.041	.029

Figure 2 Model:	Mean	Sample St.Dev.		Mean	Sample St.Dev.
R^2S:G	.134	.068	R^2E:G	.118	.064
R^2S:G,AP	.194	.080	R^2E:G,AP	.151	.071
R^2S:G,AP,C	.211	.085	R^2E:G,AP,C	.164	.074
R^2S:G,AP,K	.214	.084	R^2E:G,AP,K	.174	.067
R^2S:G,AP - R^2S:G	.060	.044	R^2E:G,AP - R^2E:G	.033	.024
R^2S:G,AP,C - R^2S:G,AP	.017	.013	R^2E:G,AP,C - R^2E:G,AP	.013	.014
R^2S:G,AP,K - R^2S:G,AP	.020	.015	R^2E:G,AP,K - R^2E:G,AP	.024	.019

Figure 1

Analysis Design for Testing Direct and Indirect
Causal Links of Hierarchical Model of the Taxonomy

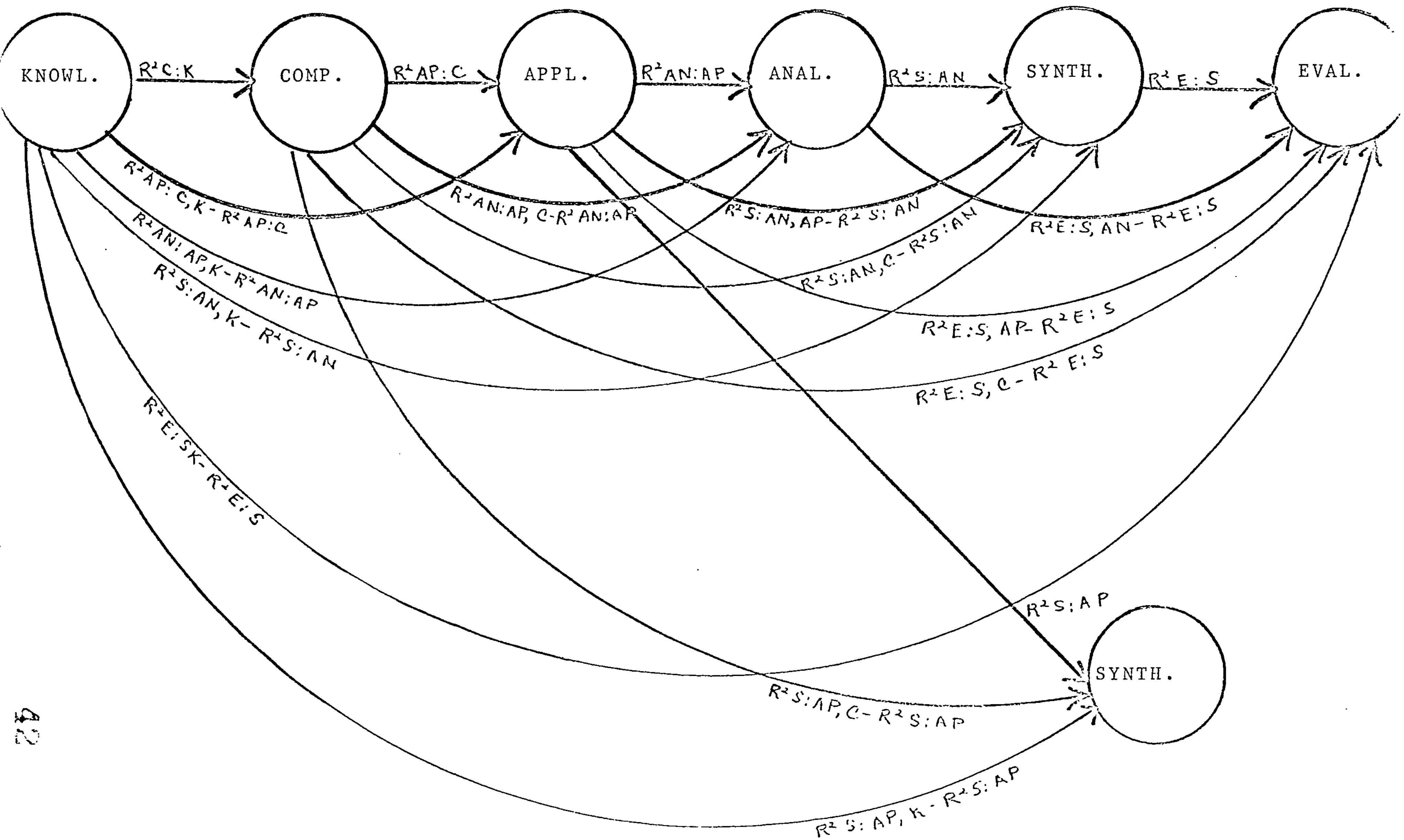

Figure 2

Analysis Design for Testing Effect of G-Factor on
Direct and Indirect Causal Links of Hierarchical Model of the Taxonomy

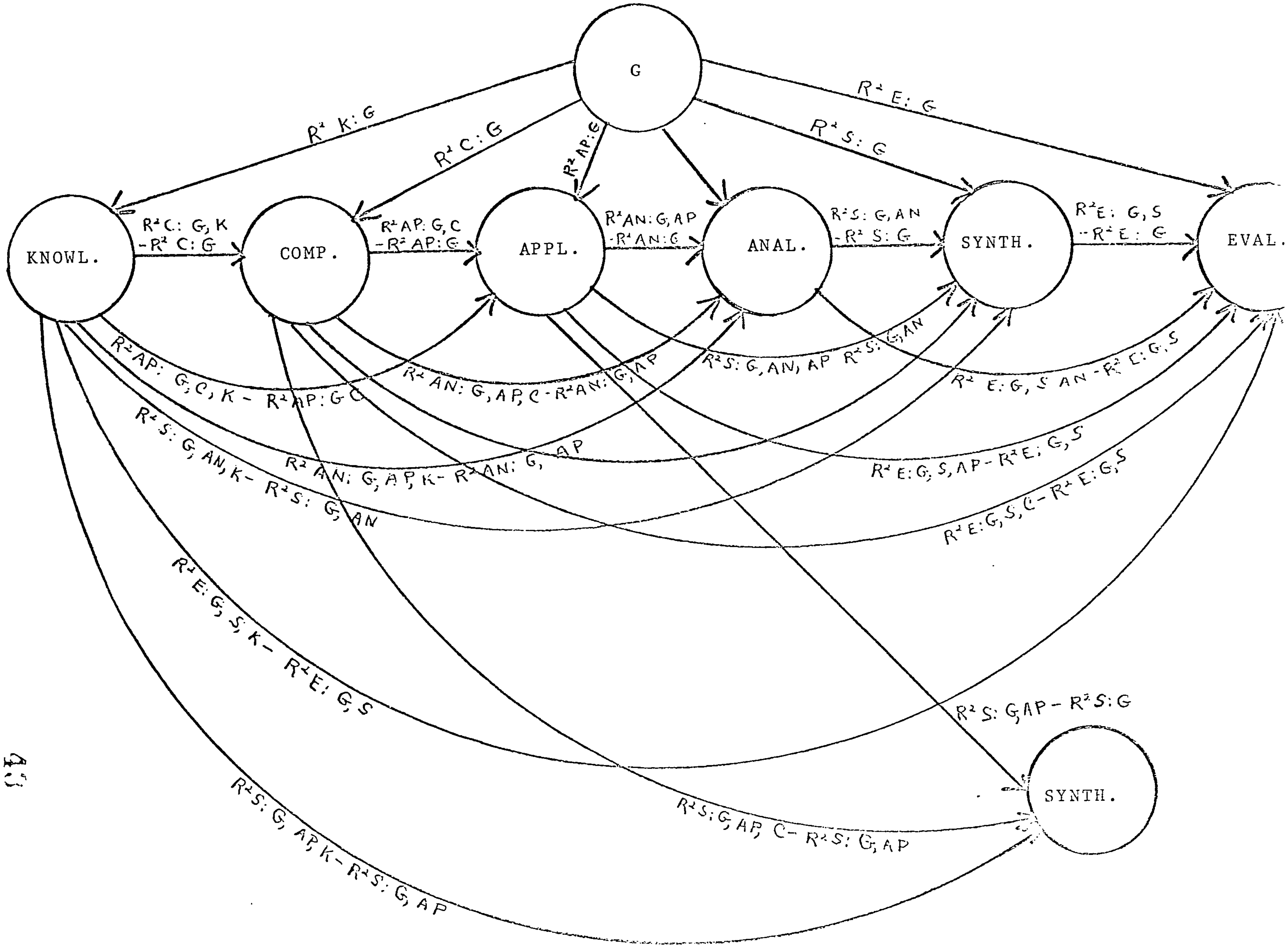

Figure 3

Average Variances Explained by Multiple Regressions for Total 16 Replications (see Table 4) for Assumed Taxonomic Hierarchy Compared to Suggested Y-Shaped Structure

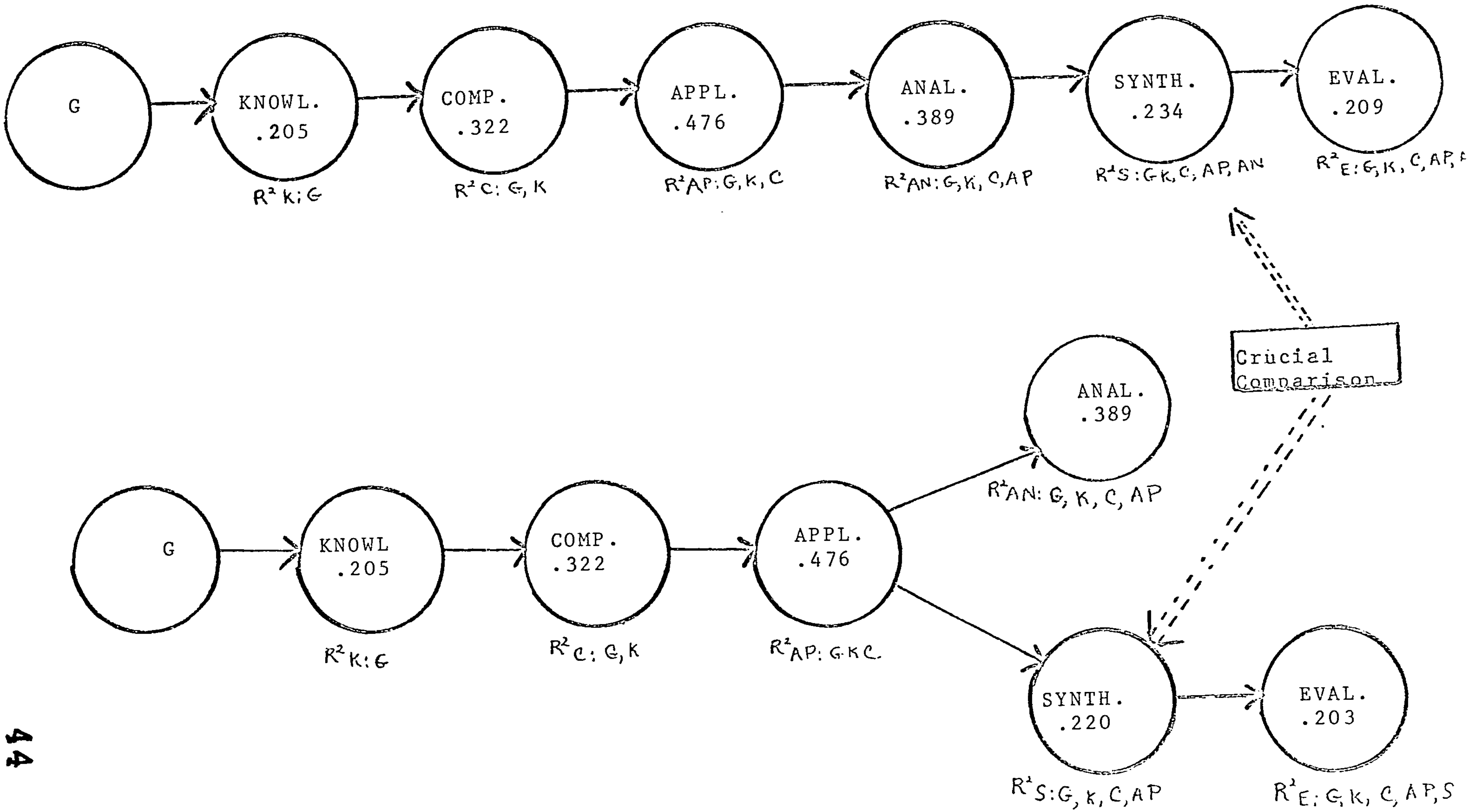

Figure 4

Summary of Causal Model Analyses (see Figure 1) of
Direct and Indirect Causal Link Averages (R .04) for Total 16 Replications
(see Table 5)

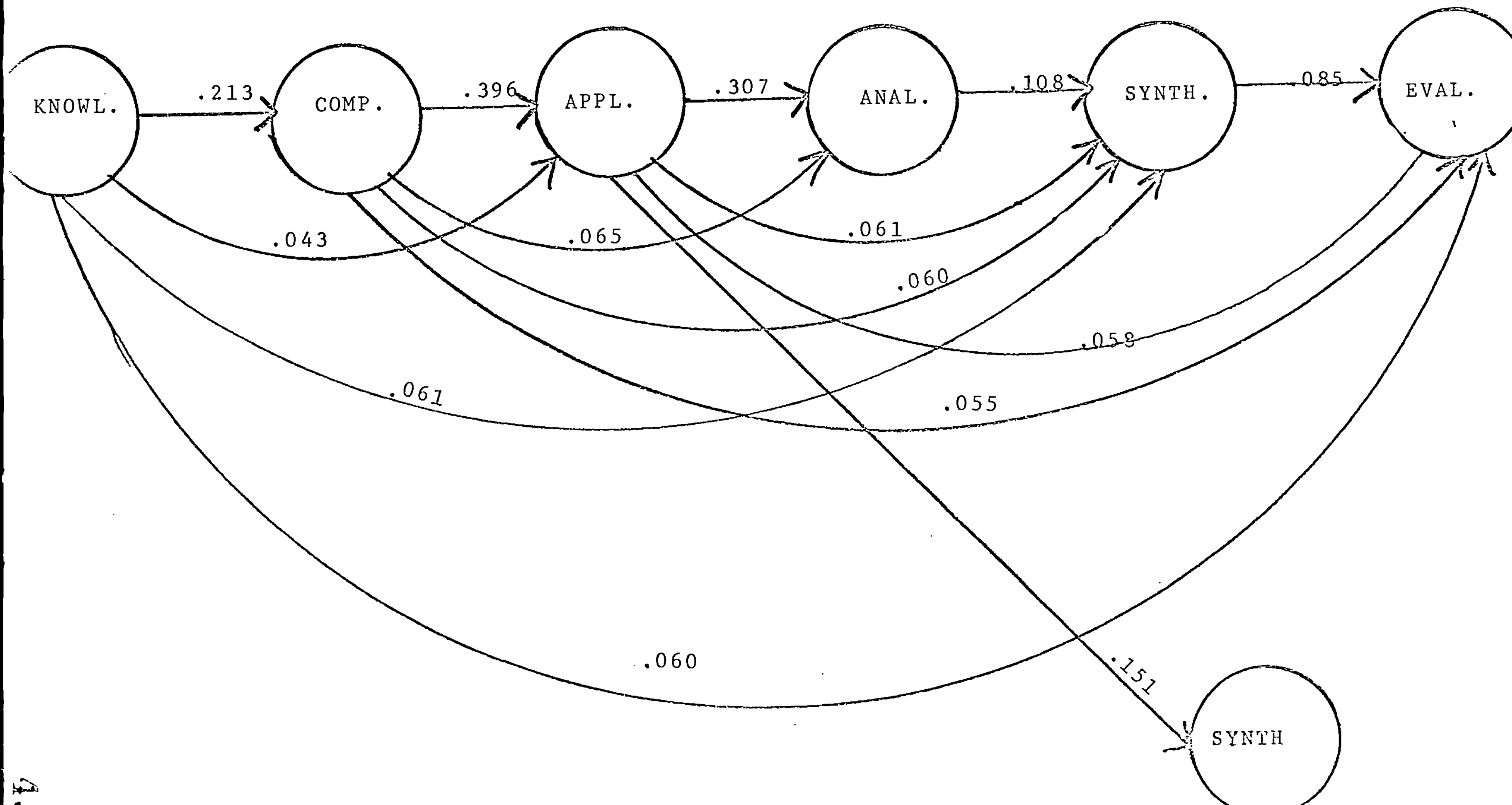

Figure 5

Summary of Causal Model Analyses with G-Factor (see Figure 2)
Direct and Indirect Causal Link Averages (R^2 .04) for Total 16 Replications
(see Table 6)

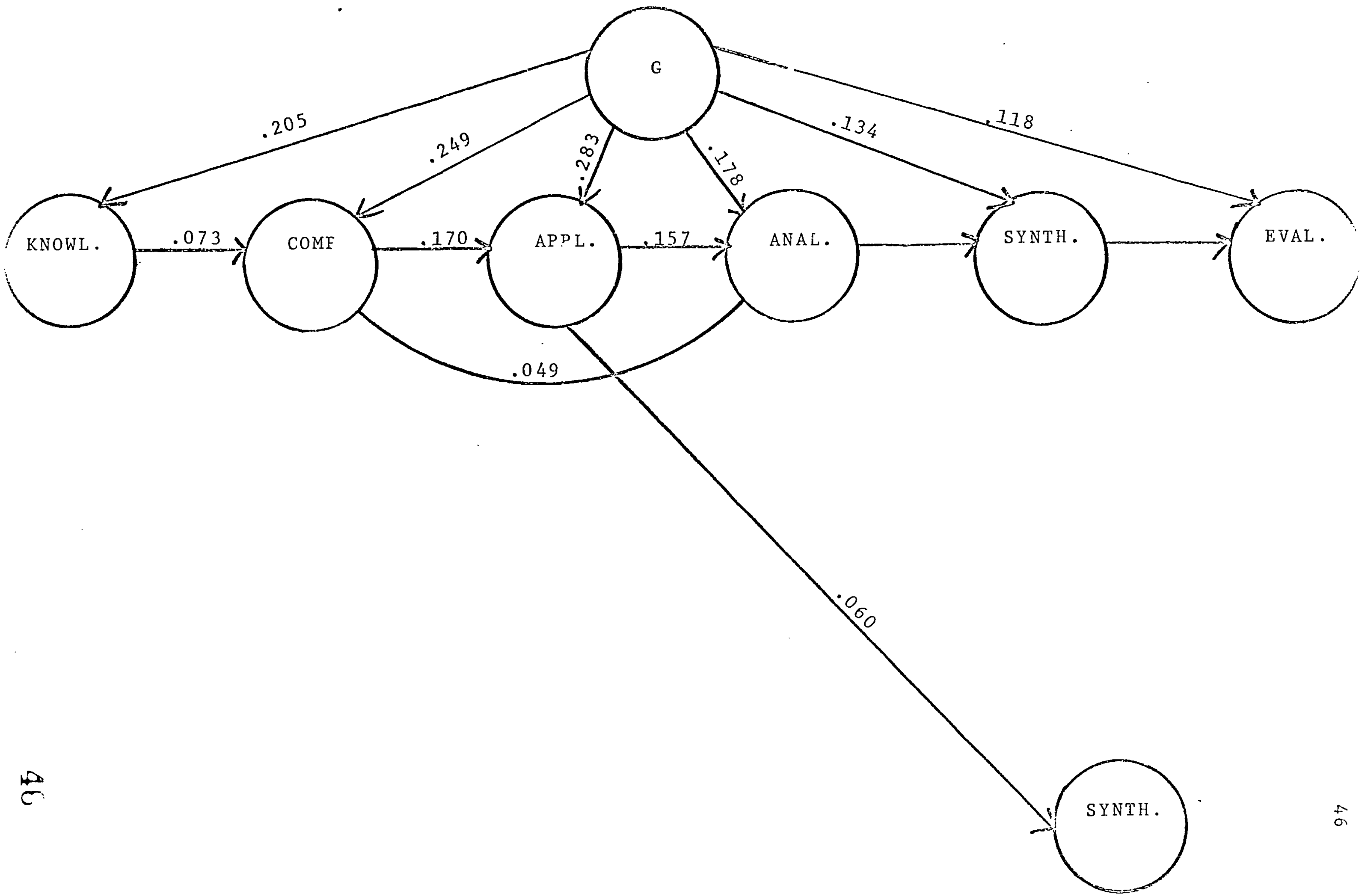

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Figure 6

Redrawing of Figure 5 to Better Illustrate Structure of Taxonomic Levels

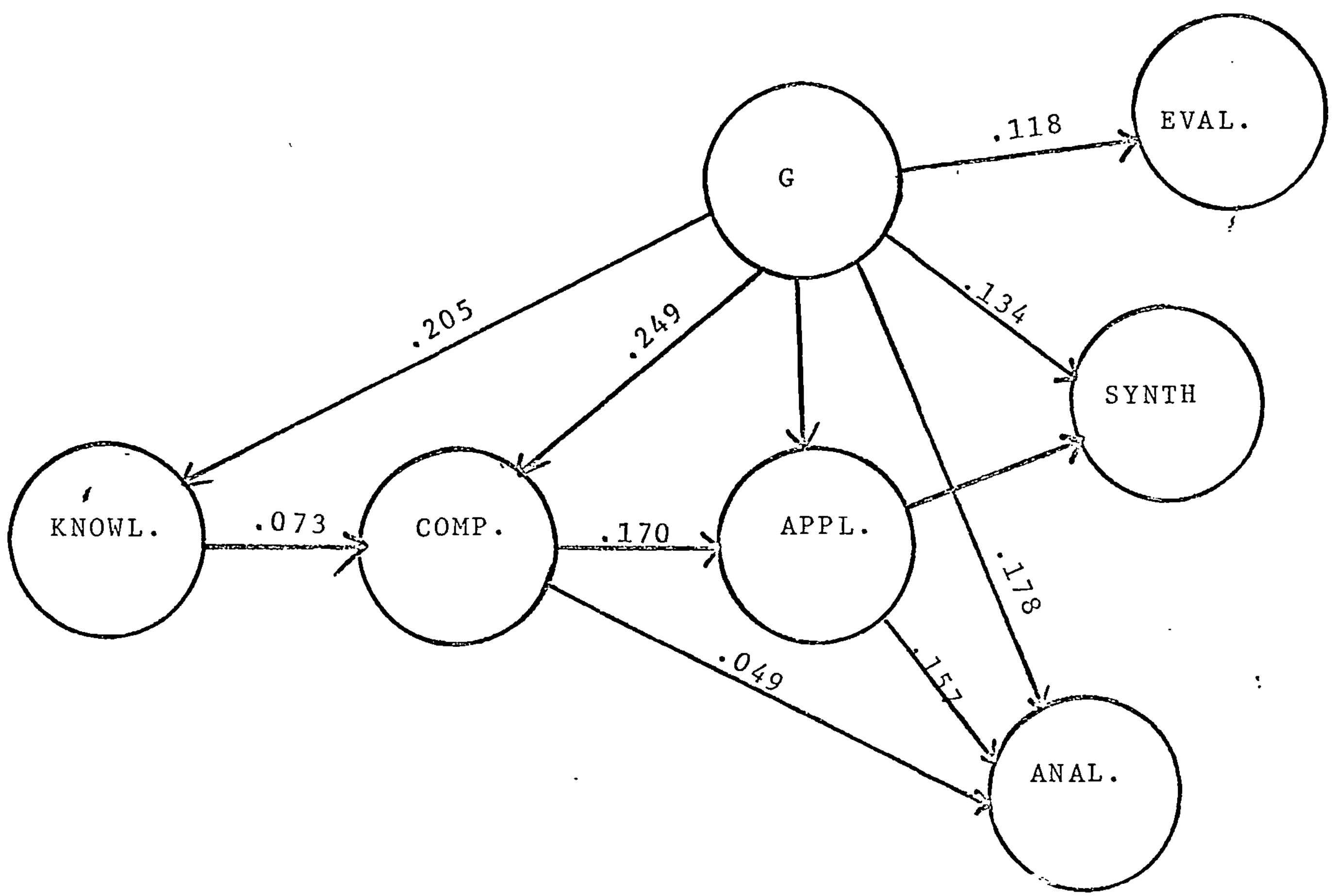

Figure 7

Summary of Causal Model Analyses (See Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 9 across Contents
(see Table 7)

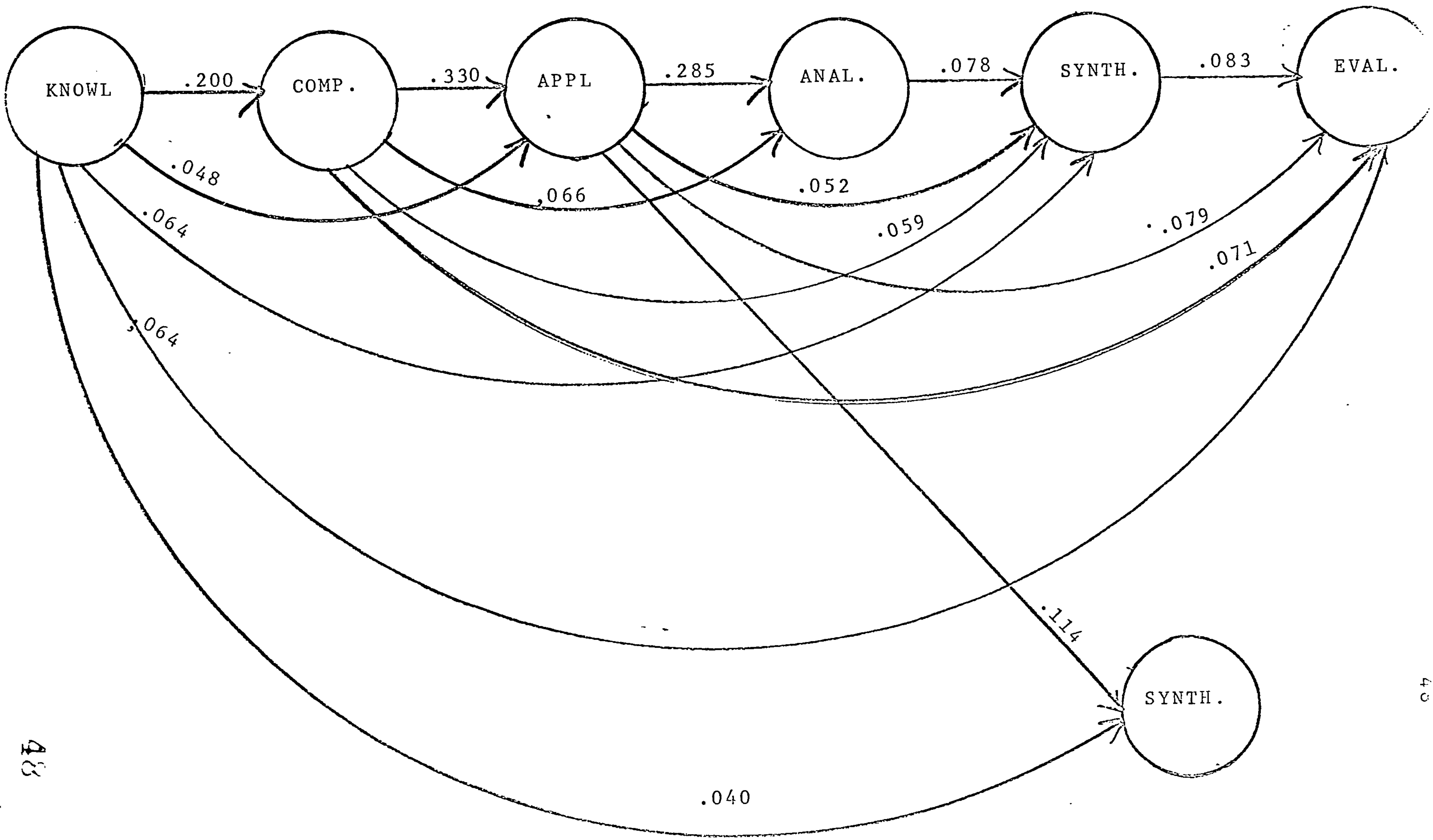

Figure 8

Summary of Causal Model Analyses with G-Factor (See Figure 2) of
Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 9 across Contents
(see Table 15)

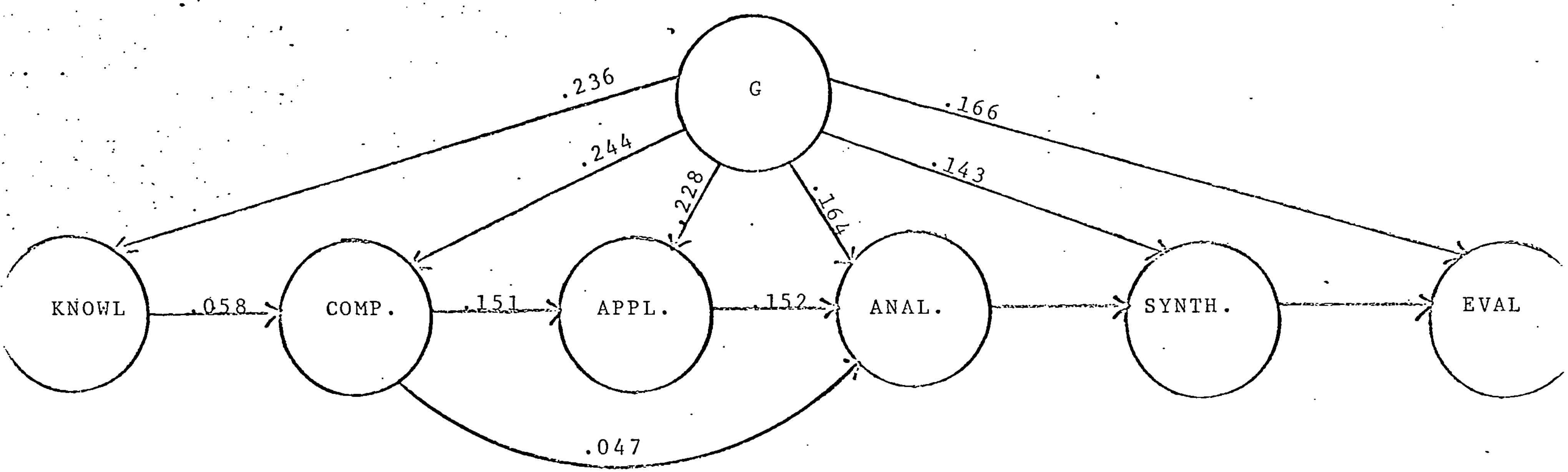

Figure 9

Summary of Causal Model Analyses (See Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 10 across Contents
(see Table 8)

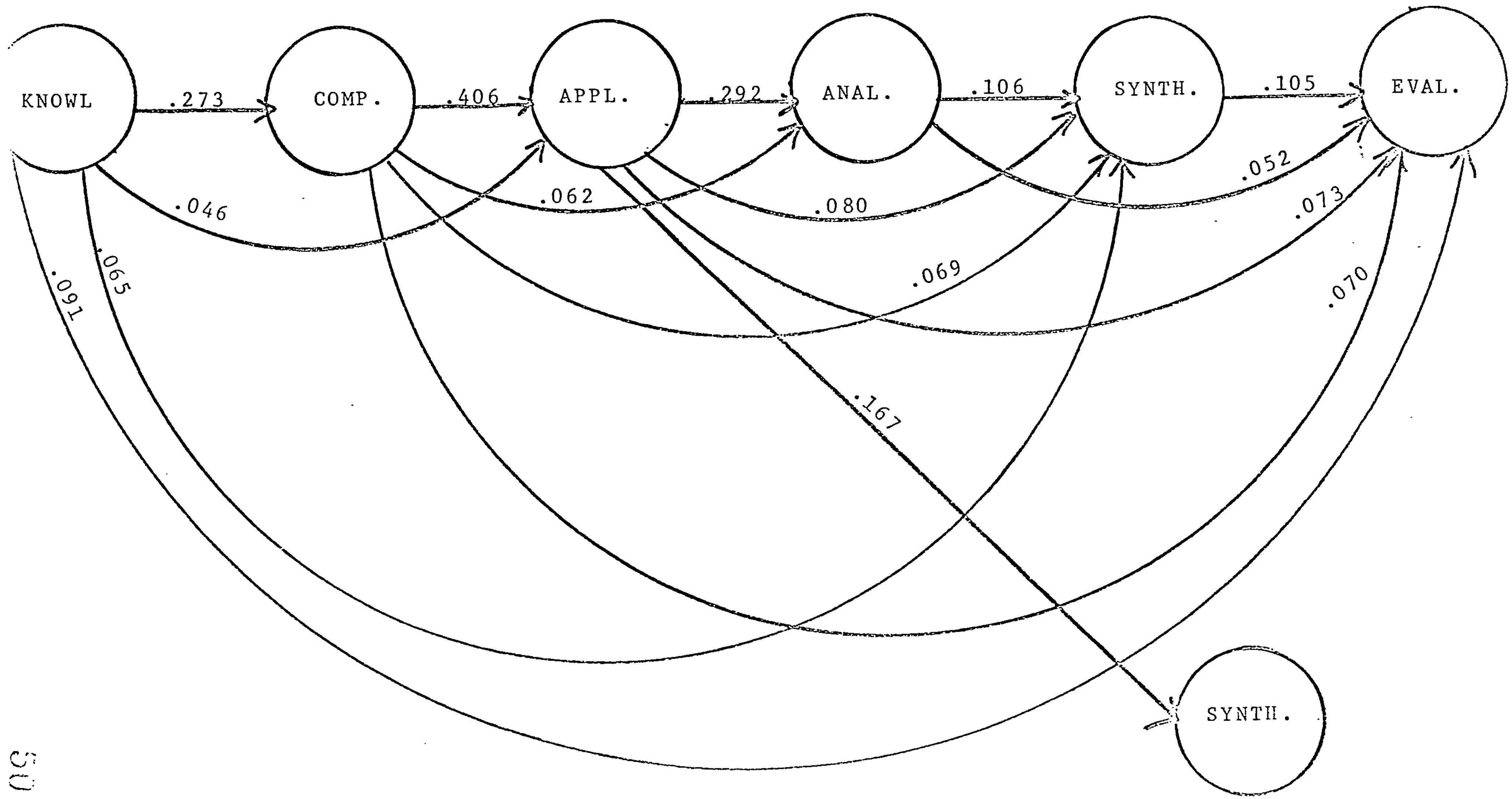

Figure 10
Summary of Causal Model Analyses with G-Factor (see Figure 2) of
Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for grade 10 across Contents
(see Table 16)

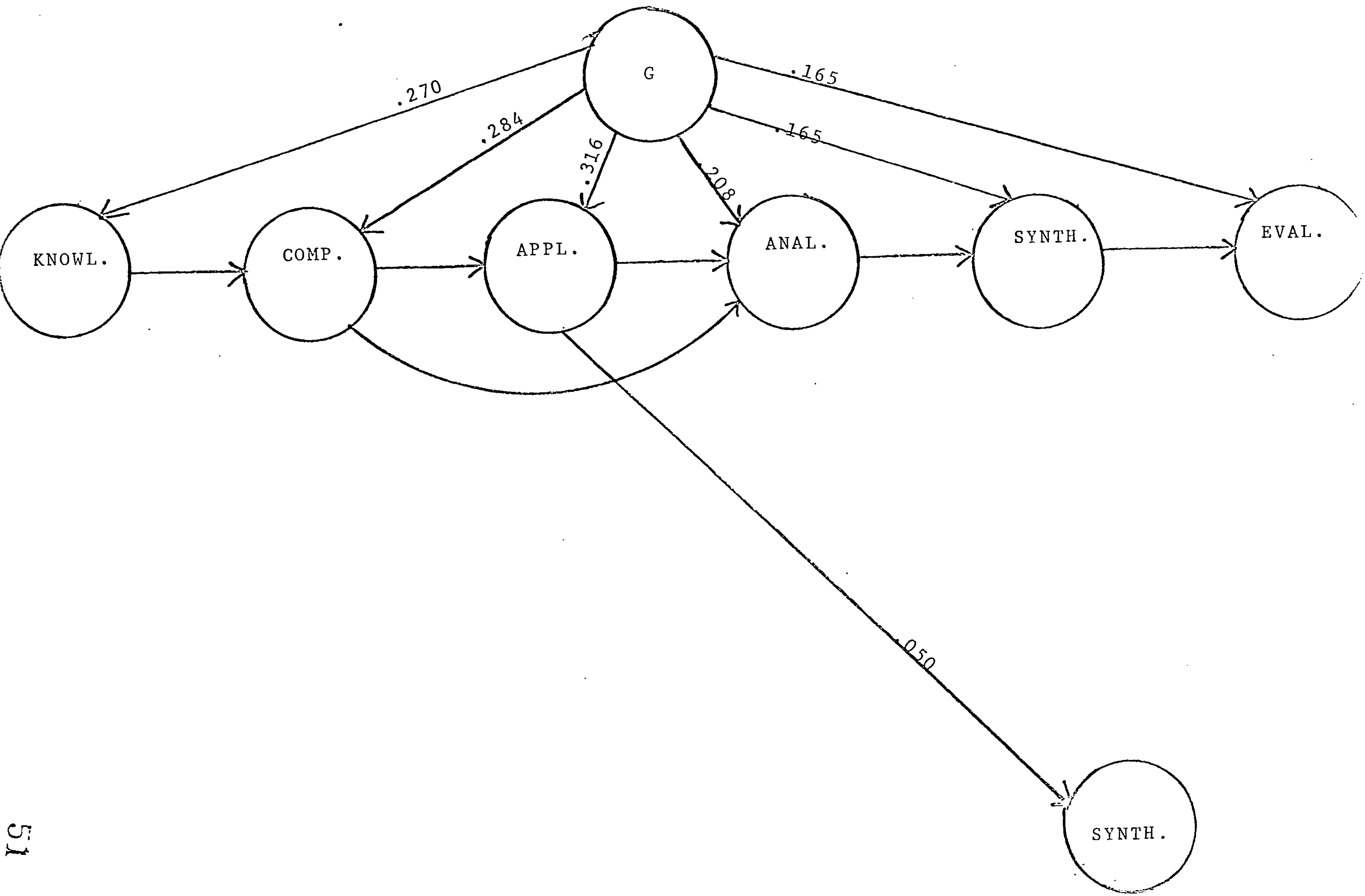

Figure 11

Summary of Causal Model Analyses (See Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 11 across Contents
(see Table 9)

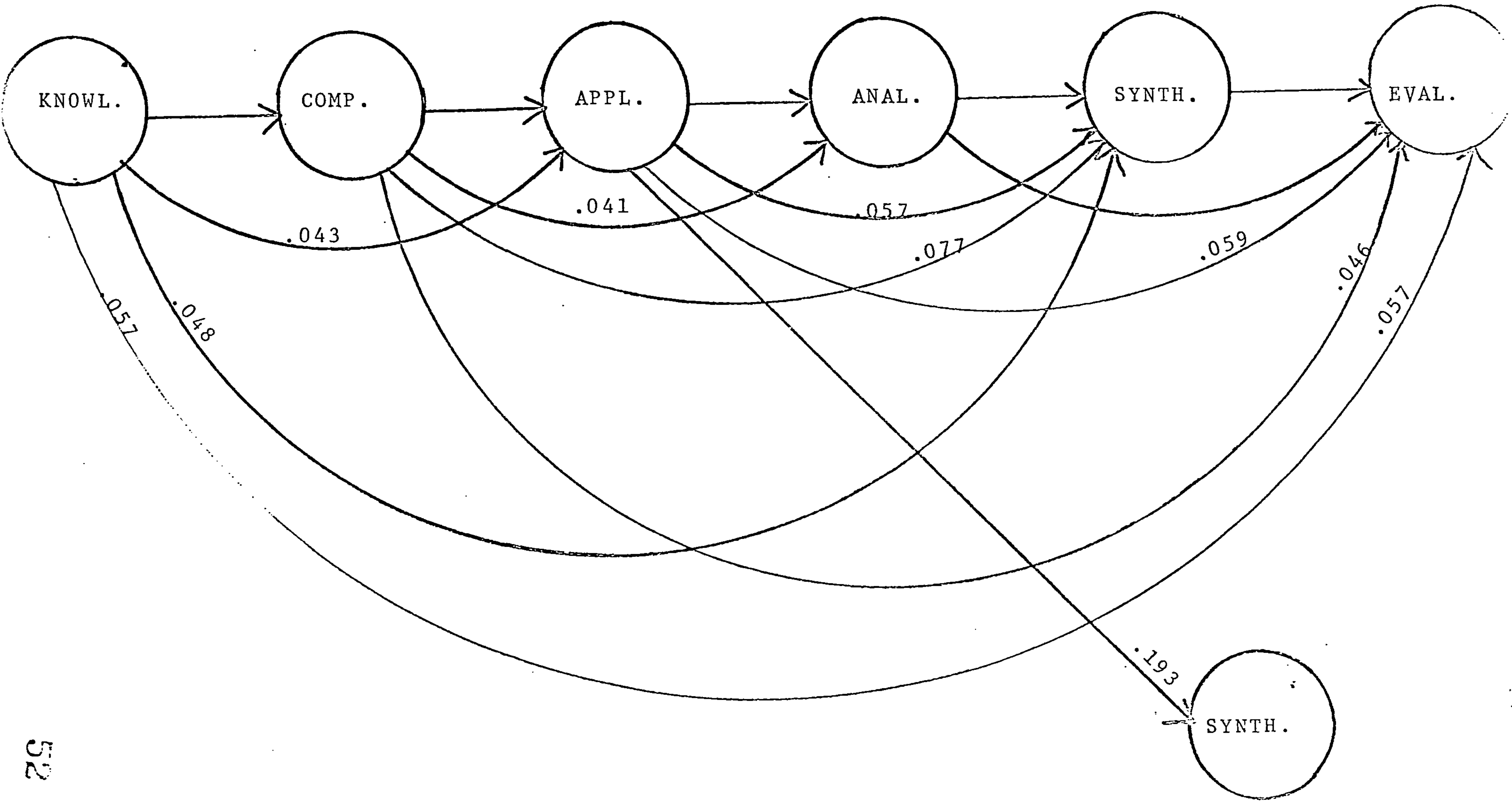

Figure 12
Summary of Causal Model Analyses with G Factor (See Figure 2) of
Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 11 across Contents
(see Table 17)

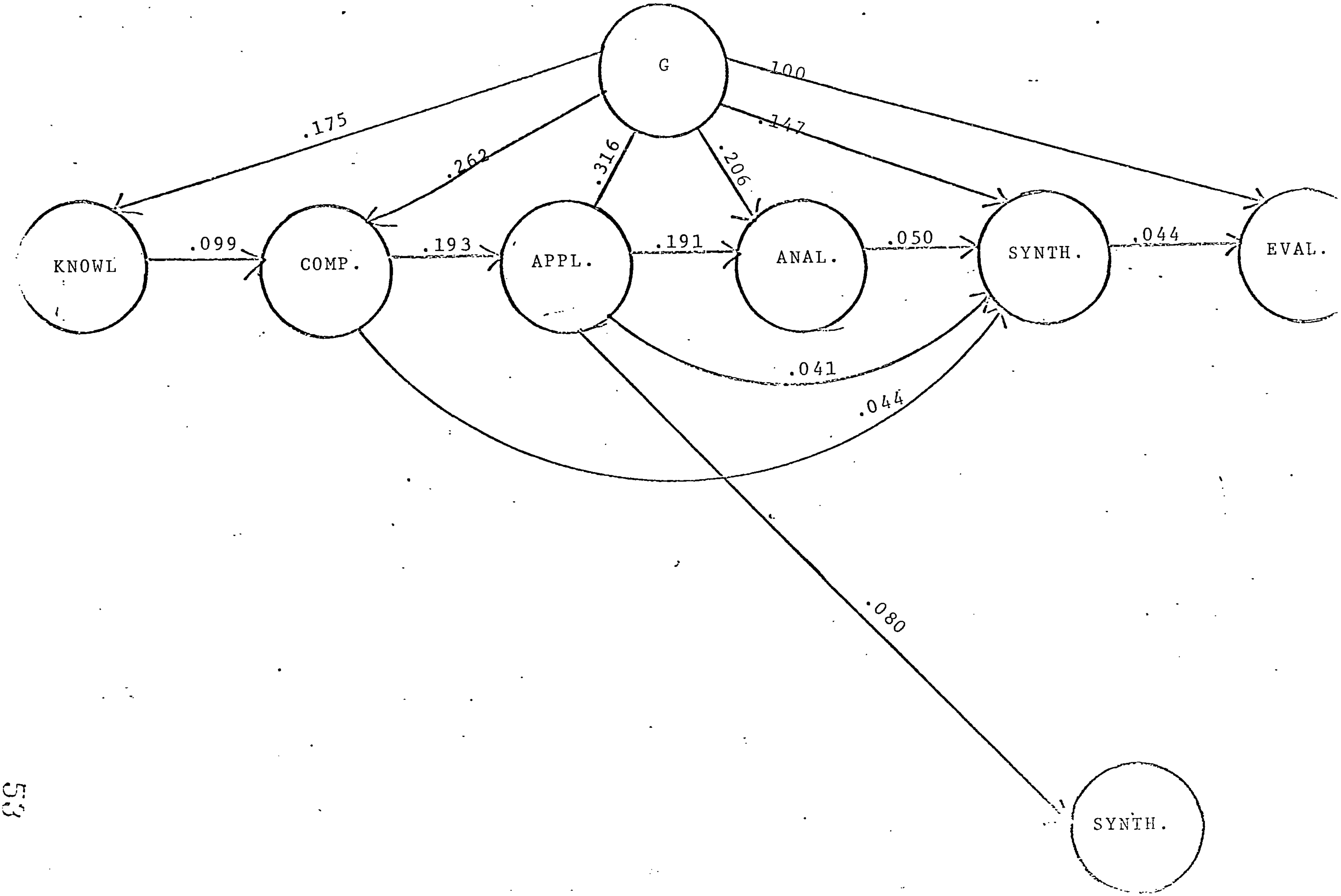

Figure 13

Summary of Causal Model Analyses (see Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 12 across Contents
(see Table 10)

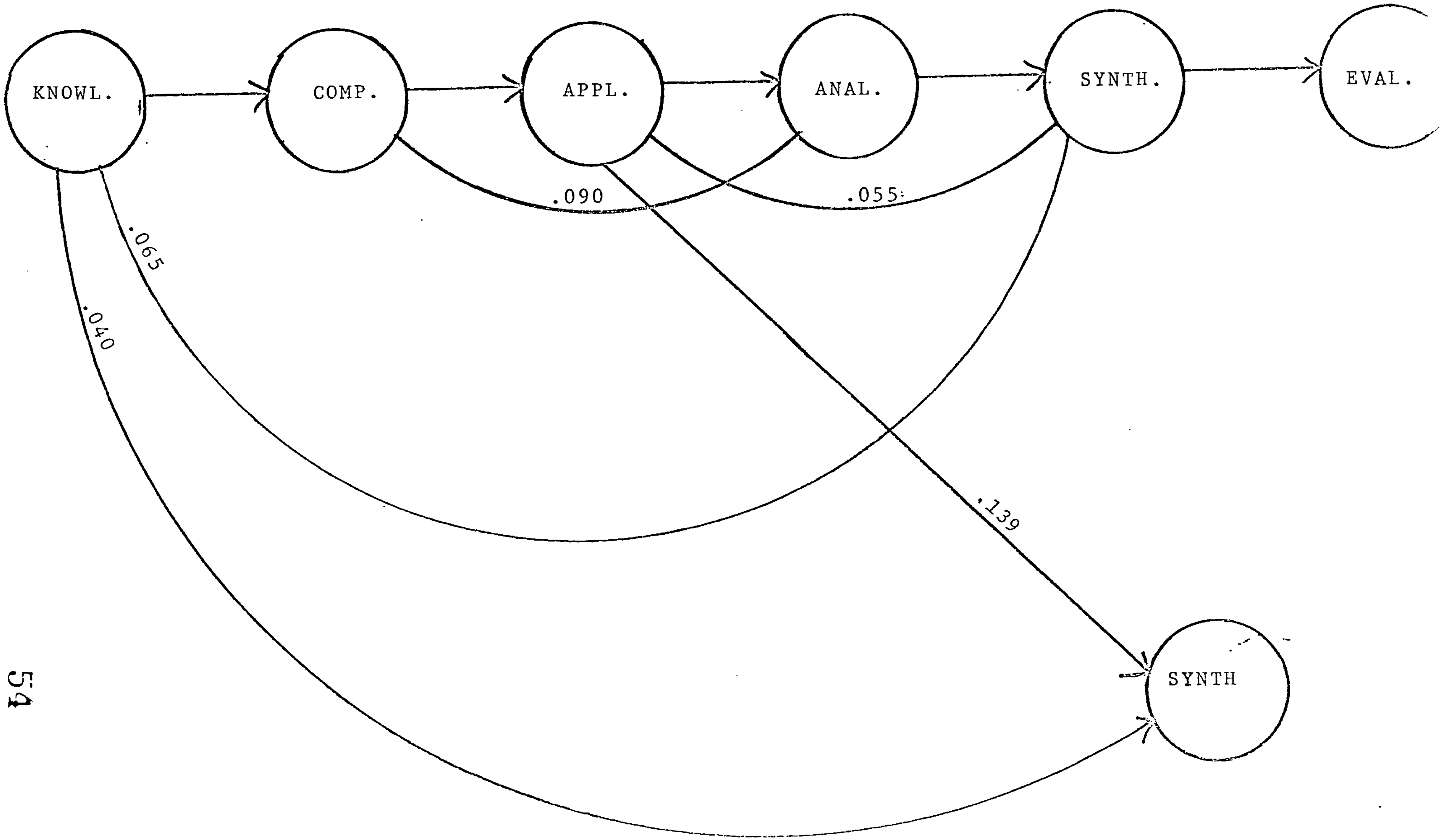

Figure 14

Summary of Causal Model Analyses with G-Factor (see Figure 2) of Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Grade 12 across Contents (see (see Table 18)

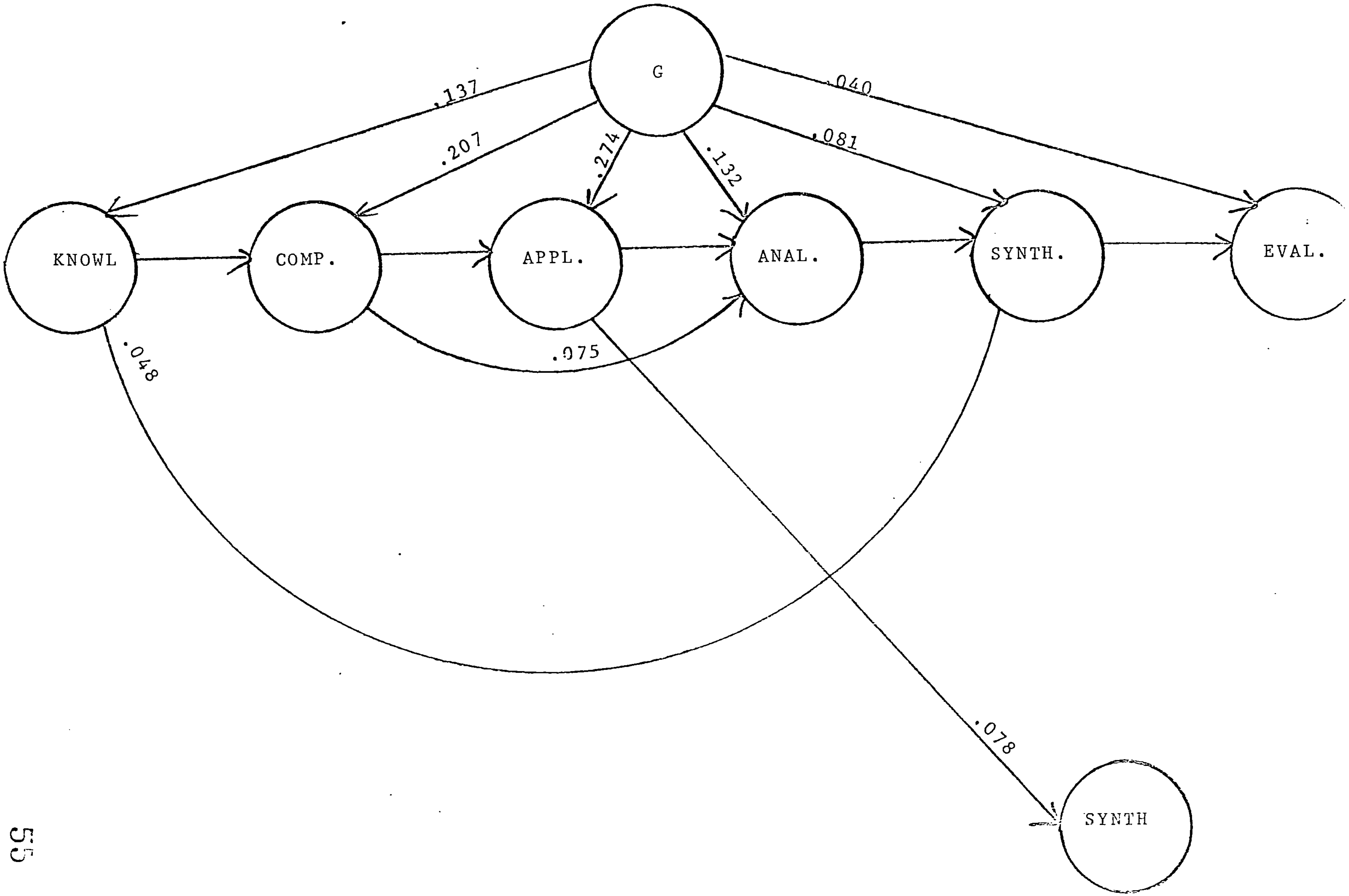

Figure 15

Summary of Causal Model Analyses (see Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Atomic Structure across Grades

(see Table 11)

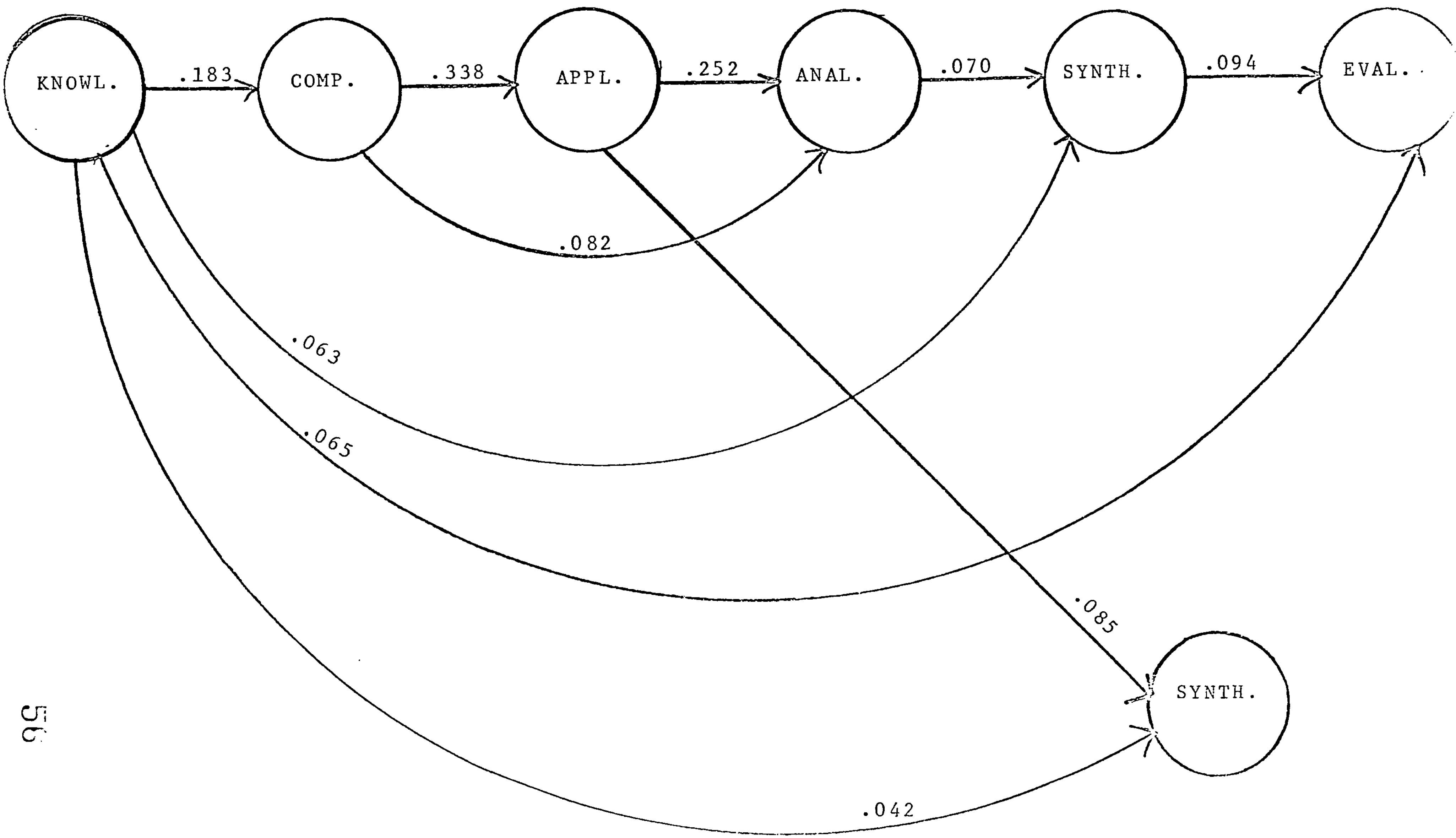

Figure 16

Summary of Causal Model Analyses with G-Factor (see Figure 2) of Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Atomic Structure across Grades (see Table 19)

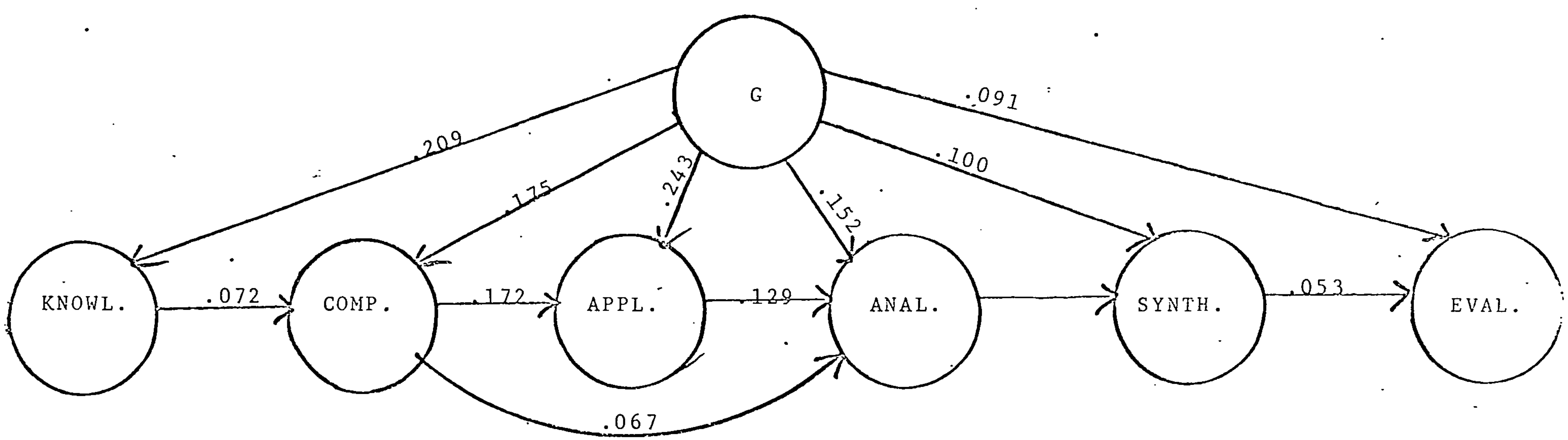

Figure 17

Summary of Causal Model Analyses (see Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Glaciers across Grades
(see Table 12)

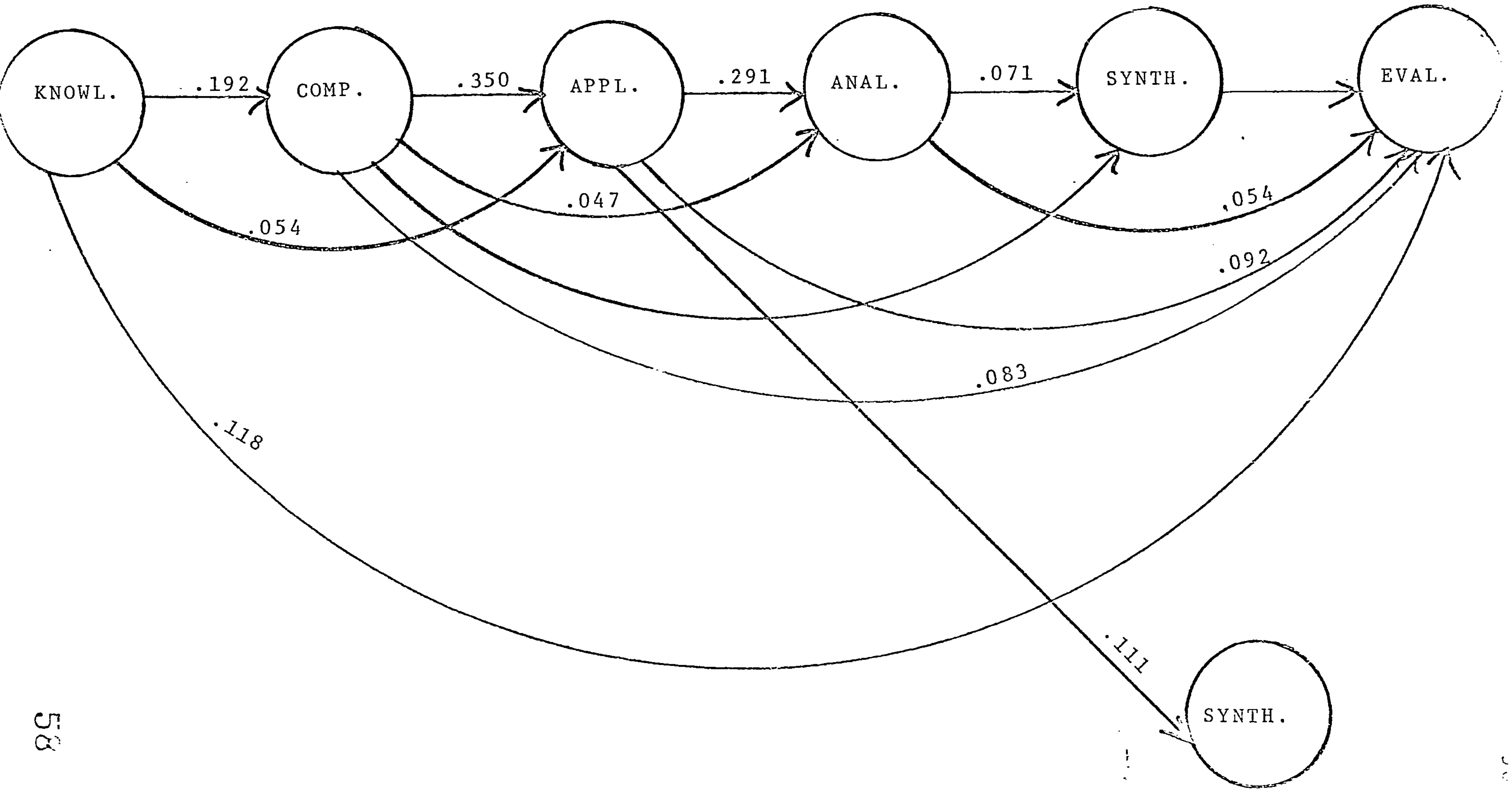

Figure 18
Summary of Causal Model Analyses with G-Factor (see Figure 2) of Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Glaciers across Grades (see Table 20)

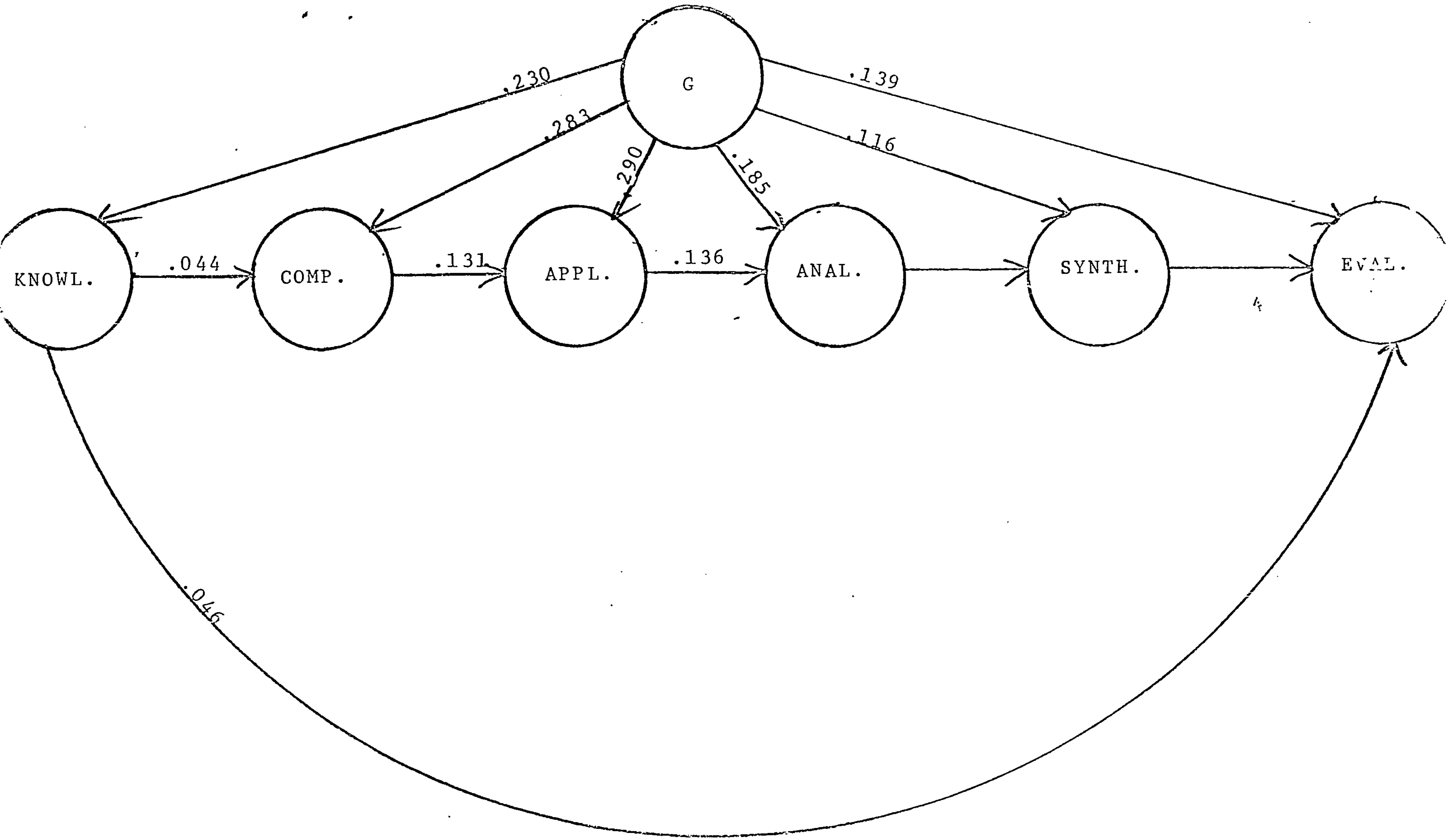

Figure 19

Summary of Causal Model Analyses (see Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \gtrsim .04$) for Earthquake across Grades

(see Table 13)

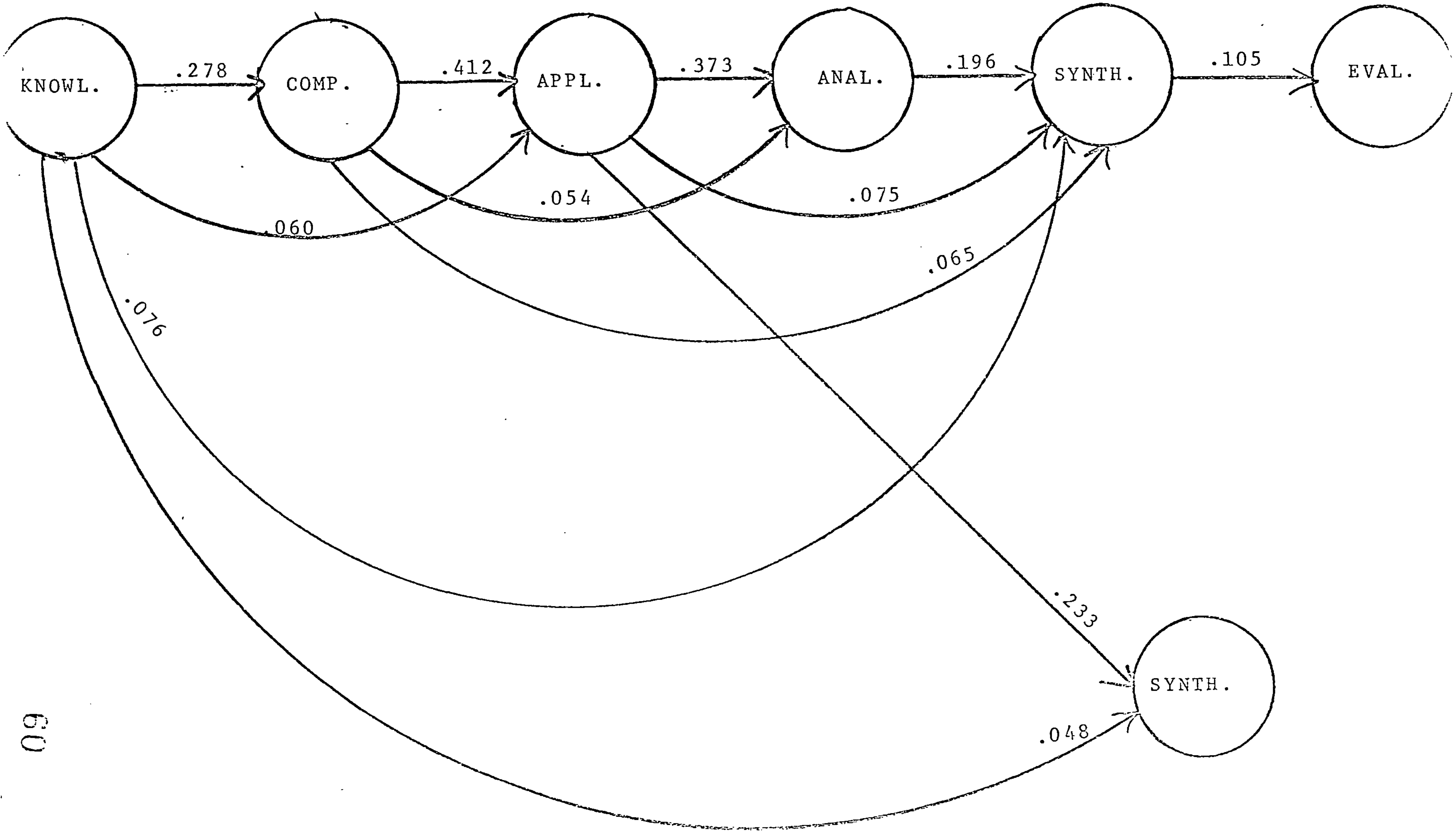

Figure 20
Summary of Causal Model Analyses with G-Factor (see Figure 2) of Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Glaciers across Grades (see Table 21)

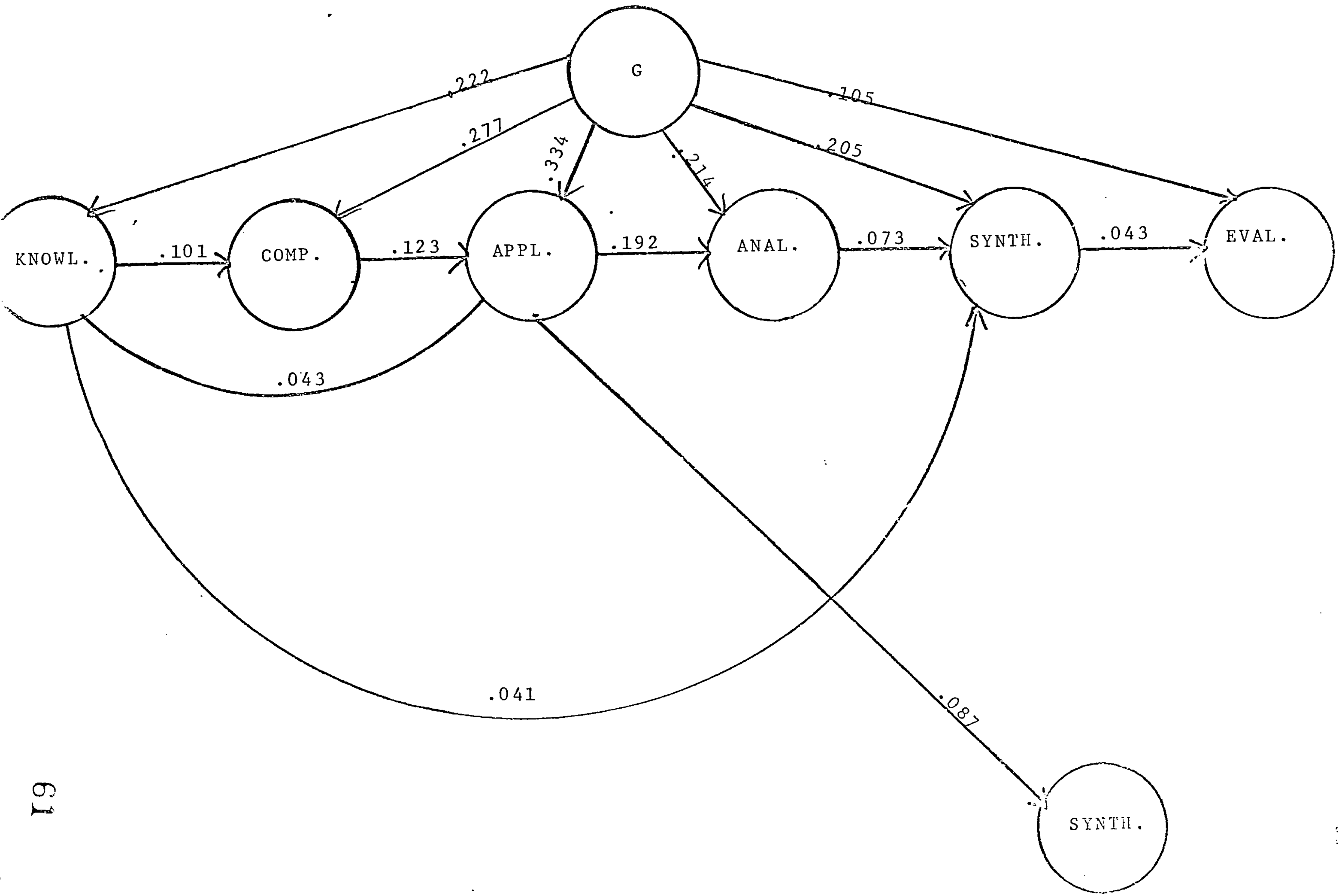

Figure 21

Summary of Causal Model Analyses (see Figure 1) of

Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Econ. Growth across Grades
(See Table 14)

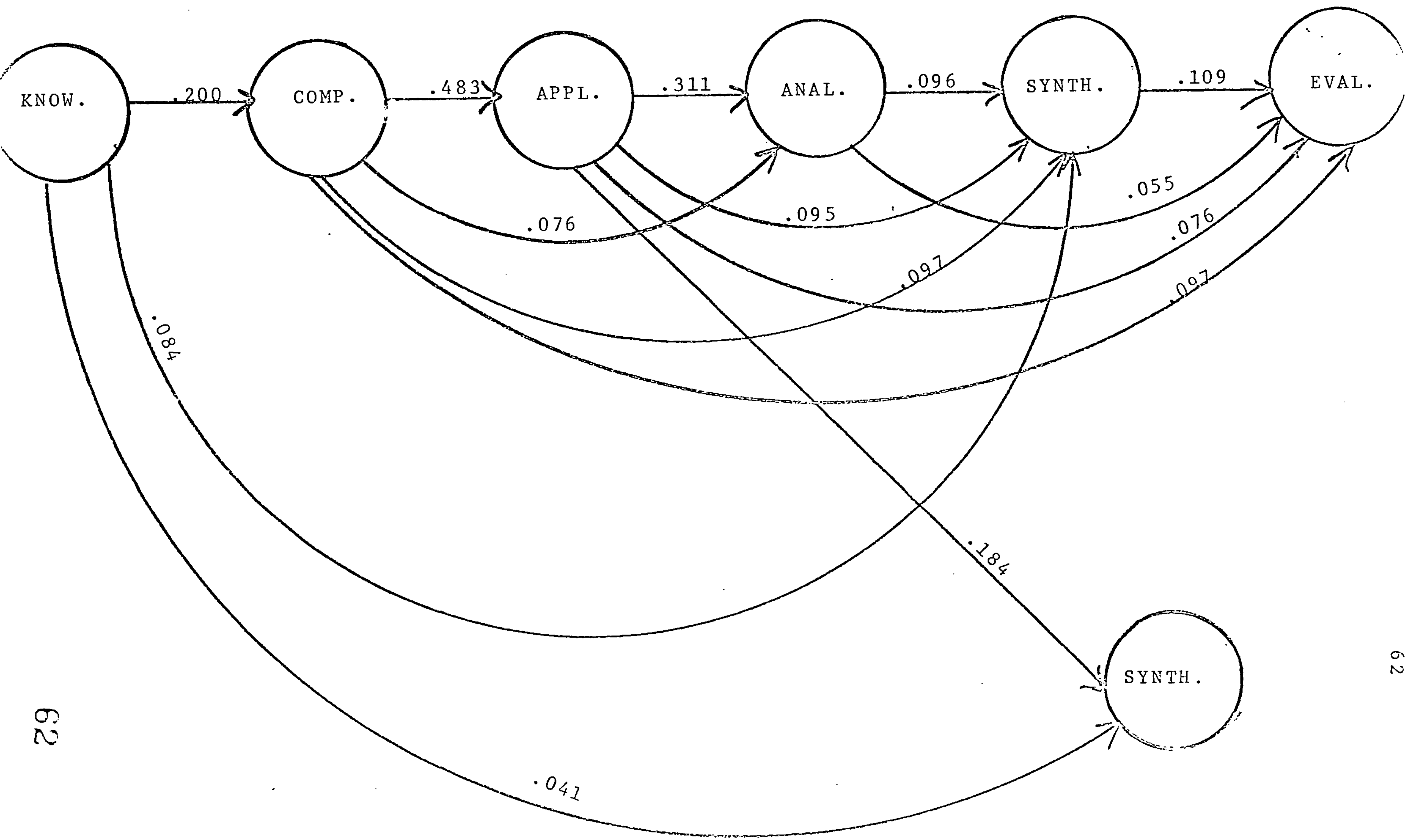

Figure 22

Summary of Causal Model Analyses with G-Factor (See Figure 2) of Direct and Indirect Causal Link Averages ($R^2 \geq .04$) for Econ. Growth across Grades

(see Table 22)